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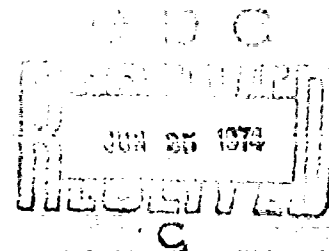
AD919994

AFML-TR-74-10  
Volume II

## **SLEEVE COLDWORKING FASTENER HOLES**

Volume II--Appendixes

Joseph L. Phillips  
Manufacturing Research and Development  
Boeing Commercial Airplane Company



TECHNICAL REPORT AFML-TR-74-10, VOLUME II

February 1974

Distribution limited to U.S. Government agencies only; test and evaluation data; February 1974. Other requests for this document must be referred to Manufacturing Technology Division, Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio 45433

Air Force Materials Laboratory  
Manufacturing Technology Division  
Air Force Systems Command  
Wright-Patterson Air Force Base, Ohio

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Volume II--Appendixes

Joseph L. Phillips

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## FOREWORD

This technical report covers all work performed under Contract F33615-72-C-1630 from 1 June 1972 to 30 November 1973. This manuscript was released for publication by the author in February 1974.

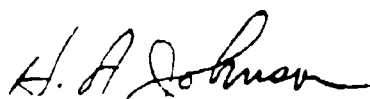
This contract with The Boeing Commercial Airplane Company was initiated under Manufacturing Methods Project 746-2, "Sleeve Coldworking Fastener Holes." It was conducted under the technical direction of Captain Carlan Silha, Metals Branch (AFML/LTM), Manufacturing Technology Division, Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio.

This program was accomplished at The Boeing Commercial Airplane Company in Seattle, Washington, with Mr. Richard G. Christner as program manager, Mr. Joseph L. Phillips as principal investigator, and Mr. Ray Hendricks as primary coordinator and director of the testing program. Other personnel that supported the program in Boeing were DeVere Lindh, Dave Reese, Tom Kane, Burke Dykes, Walt Swift, and Merrell Christianson.

Publication of this final technical report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas. Your comments are solicited on the potential utilization of the information contained herein as applied to your present and/or future production and/or your maintenance rework. Suggestions concerning additional manufacturing methods on this or other subjects will be appreciated.

This program was accomplished as part of the Air Force Manufacturing Technology Program, the primary objective of which was to develop on a timely basis, manufacturing processes and techniques for use in economical production of USAF materials and components for aircraft production.

This technical report has been reviewed and approved for publication.



H. A. JOHNSON  
Chief, Metals Branch  
Manufacturing Technology Division

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This technical report has been reviewed and approved for publication.



H. A. JOHNSON  
Chief, Metals Branch  
Manufacturing Technology Division

## ABSTRACT

In this 21-month program, optimized process parameters for sleeve coldworking of fastener holes have been developed, and the effects of process and application parameters on structural performance have been defined for selected aluminum, titanium, and high-strength steel alloys. The sleeve coldworking process for fastener holes is a process that uses a tapered mandrel in conjunction with a disposable, prelubricated sleeve to compressively prestress a significant size zone around each hole which offsets the stress concentration of the hole itself. The sleeve method allows higher degrees of prestressing than possible with other methods and offers potential for significant improvements in fatigue performance. In addition, it does not require precision controls germane to other fatigue-rated hole preparation/fastener installation systems. This technical report covers the results of this 21-month program. In addition to definition of optimized methods and the effects of process and application variations upon structural performance, the results include performance and economics comparisons for the process with other fatigue-rated hole preparation/fastener systems.

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**APPENDIX I**

**MATERIAL PROCUREMENT TEST REPORTS**

0.010 - 0.249								
<i>1/4" Thick</i> <b>TYPICAL TEST REPORT 0.250 - 0.499</b> <b>2024-T81 Flat Alumin Sheet</b> <b>(T851) Plate</b>								
SPECIFICATION QQA 250/4 Latest Revision								
PRODUCING MILL Alcoa					HEAT/LOT No.			
CHEMICALS								
	SI	FE	CU	MN	MG	CA	Z	TI
MIN			3.8	.30	1.2			
MAX	.50	.50	4.9	.9	1.8	.10	.25	
	NI	PR	AL	OTHER	CARBON	PHOS	SUL	TIN
MIN								
MAX				Bal	.15			
MECHANICAL PROPERTIES								
	TENSILE		YIELD		ELONGATION		HARDNESS	
MIN	67,000		58,000		5% - 2"			
MAX								
<b>TESTS &amp; INSPECTION</b> THE ABOVE TEST DATA CONFORMS TO THE REQUIREMENTS OF THE SPECIFICATION AS NOTED. THE MATERIAL HAS BEEN INSPECTED AND FOUND IN COMPLIANCE TO THIS SPECIFICATION.								
By <i>[Signature]</i> TEST REPORT DEPT.								

Mill Test Report - 2024 T851 Strength Test Data and Chemistry

<b>G.O. CARLSON Inc</b> Producers of Stainless Steel <i>Nickel Alloys and Titanium</i> THORNDALE, PA. 19378		<b>NC TEST REPORT</b> 8/1/72	
SOLD TO: The Boeing Company Commercial Airplane Group P.O. Box 3707 Seattle, Washington, 98124		ORDER NO: 32547 CUST NO: 6-966576-41351 MARK: 6-966576-41351	
INVOICE: Same Co. Boeing Field Bldg. 3-304 Door 8, Gate C-39 Seattle, Washington, 98124		DATE OF ORDER: 8/1 NO. COPIES: 4 ATTN: Pur. Dept. TYPED BY: ssd	
SHIP TO: United Parcel Service-Blue Label		NOTARIZED TEST REPORTS: 4 CHEMS. & MECHANICAL PROPS. (1) WITH SHIPMENT	
ROUTING (ACTUAL):		1/4 TO CUST 2/4 TO CUST	

TYPE: CARLSON C6 AL-4V TITANIUM HRA & DESCALED MIL-T-9046F TYPE III COMP.C ANNEALED, DESCALED #1 FINISH			STOCKING: Try 7-28 or 80088		
QTY	SIZE	PRICE	QTY	SIZE	PRICE
2	3/4 x 2-3/4 x 15-1/2	11	2	3/4 x 3-1/2 x 15-1/2	14
2	3/4 x 2 x 15-1/2	8	2	3/4 x 12-1/2 x 12-1/2	20
		53			

ALL ITEMS: ABRASIVE CUT GRAIN TO RUN DIRECTION OF ROLLING  
 PRIORITY TRYING DO-A1  
 CONTRACT # 3615-72-C-1630

CHEMICAL ANALYSIS										HYDROGEN		
Item	QTY	Heat No.	C	N	Fe	O <sub>2</sub>	H <sub>2</sub>	Yt	Al	Sn	Va	CHECK
1	7	A41531-18	.024	.015	.20	.16	.0010		84.5.82		4.08	.0054

MECHANICAL TESTS		YIELD STRENGTH	TENSILE	% ELONG	% RED	BRINELL	TEMP
QTY	HEAT NO.	1/4 OFFSET	STR. 9.31	IN 2"	OF AREA	PER SQUARE	
3/4	A41531-18	113,400	146,800	12.0	33.0	302	---
		113,600	148,000	11.0	34.0	302	---

SHOWN TO AND S. BECH BEH. BEFORE METHOD: 1 DAY OF AUG 72  
 I HEREBY CERTIFY THE ABOVE FIGURES ARE CORRECT AS CONTAINED IN THE REPORT OF THE TEST LAB.

G.O. CARLSON, INC.

Mill Test Report - Ti-6Al-4V Titanium Strength Test Data and Chemistry

# FRIEND METALS CO. INC.

1650 SO. SINCLAIR STREET

ANAHEIM, CALIFORNIA 92805

(714) 639-5610

## CERTIFICATE OF TESTS — MILL PRODUCTS

Date October 2, 1972

S  
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D

Boeing Comm'l Airplane Co.  
P.O. Box 3707  
Seattle, Wash.

S  
H  
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P  
T  
O

Boeing, C.A.G. Revg.  
Bldg. #3-304, Door 8  
Boeing Field  
Seattle, Wash.

Customer Order No.	Our Order No.	Specification
6-966563-5835F	742	AMS-6519A
Heat Number	Quantity	Size
C23761	4 pcs.	22# 1/4" x 4" x 17" lg. each

Description of Material: 300 M, normalized & sub-critical annealed to R/c 33 Max per BAC-5617 & blanchard ground on 2 sides to (+.100"-0")

Heat Number	CHEMICAL ANALYSIS												
	C	MN	P	S	SI	CR	NI	MO	V	TI	AL	CU	CO
C23761	.41	.78	.005	.004	1.54	.79	1.80	.42	.09				
	B	CB	TA	CB & TA		SN	H	N	O	FE			

Heat Number	MECHANICAL PROPERTIES									
	Tensile PSI	.2 % Yield PSI	% Elong in	% Red Area	BHN	Shock PSI	Temp °F	Hours	% Elong in	Grain Size
	289,000	250,000	10.3	31.8	302					7-9
	292,000	251,000	10.0	30.4						
	291,000	246,000	10.0	33.2						
	293,000	247,000	9.8	31.8						

AMS-2300-F/S=0/0

Jominy: 56.5 @ 8/16  
55.5 @ 20/16

Macro: OK

Mill: Latrobe

THIS IS TO CERTIFY TO THE BEST OF OUR KNOWLEDGE AND BELIEF, THAT THE VALUES SHOWN ARE CORRECT AND TRUE AND THAT THE MATERIAL COMPLIES WITH THE REQUIREMENTS OF THE SPECIFICATIONS SHOWN.

*[Signature]*

2M 7 77 0728

## APPENDIX II

### PHASE I DATA

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# PHASE I TASK 1 - MANDREL TAPER DETERMINATION

TEST NUMBER: IB1 TEST PLATE NUMBER: 1

MANDREL: ST 5300 C8M- ( I-O-N NOMINAL SIZE: 3/8" (.12)

MAX. DIA. MANDREL: .3538" MANDREL MATERIAL: H-11 nitrided MANDREL TAPER: .015 inch/inch

PULL: X PUSH:            LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .010" MANDREL DIA. .2xSLEEVE THICKNESS: 3738

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 3/8"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after C.V.*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
D-1	3545	3545	3550	75	.0193	3655	3655	3660	-	-	-	2090	None	0110	0110	0110
D-2	3545	3550	3550	50	.0188	3670	3660	3660	-	.0040"	.0055"	1915	None	0125	0110	0110
D-3	3550	3550	3550	85	.0188	3640	3645	3650	-	-	-	1800	None	0090	0095	0100
D-4	3550	3550	3550	90	.0188	3640	3645	3645	40	-	-	1730	None	0090	0095	0095
D-5	3545	3550	3550	85	.0188	3640	3645	3650	-	-	-	1765	None	0095	0095	0100
D-6	3550	3550	3550	75	.0188	3640	3645	3650	-	-	-	1785	None	0090	0095	0100

\* To nearest 0.0005 inch

# PHASE I TASK I--MANDREL TAPER DETERMINATION

TEST NUMBER: 1B2 TEST PLATE NUMBER: 1

MANDREL: ST 5300 CBM-110 N NOMINAL SIZE: 3/8" (12)

MAX. DIA. MANDREL: .3538" MANDREL MATERIAL: H18 extruded MANDREL TAPER: .030 inch/inch

PULL: X PUSH:  LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .010" MANDREL DIA.: .25 SLEEVE THICKNESS: .3738

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 3/8"

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW*	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thru out	Retained hole expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
E-1	3560	3550	3550	85	.0188	3660	3660	3665	---	---	---	1460	None	0100	0110	0115
E-2	3545	3545	3555	85	.0193	3655	3655	3665	---	---	---	1385	None	0100	0110	0110
E-3	3545	3545	3545	85	.0193	3640	3645	3645	---	.0040	---	1275	None	0095	0100	0100
E-4	3545	3550	3550	100	.0188	3660	3660	3665	45	---	.0055	1325	None	0115	0110	0115
E-5	3545	3545	3545	85	.0193	3635	3635	3645	---	---	---	1300	None	0090	0090	0100
E-6	3550	3550	3550	75	.0193	3640	3640	3650	---	.0040	.0055	1240	None	0090	0090	0100

\*To nearest 0.0005 inch

PHASE I TASK I MANDREL TAPER DETERMINATION

TEST NUMBER IB3 TEST PLATE NUMBER 1

MANDREL ST 5300 CBW-( ) O N NOMINAL SIZE 3/8" (-12)

MAX DIA MANDREL 3539" MANDREL MATERIAL H-II-Intitrided MANDREL TAPER .045 inch/inch

PULL X PUSH  LUBRICATION Fel Pro 300 (on sleeve)

SLEEVE THICKNESS .010" MANDREL DIA 2xSLEEVE THICKNESS 3739"

TEST MATERIAL Aluminum COMPOSITION 2024-T851 STACK UP: 3/8"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
E-7	3550	3550	3550	60	.0189	3660	3660	3670	---	---	---	1200	None	0110	0110	0120
E-8	3545	3545	3550	65	.0194	3640	3640	3645	30	---	---	1110	None	0095	0095	0095
F-2	3545	3660	3545	80	.0179	3660	3665	3670	---	.0025"	.0060"	1245	None	0115	0105	0125
F-3	3545	3545	3545	80	.0194	3660	3660	3670	---	---	---	1235	None	0115	0115	0125
F-4	3545	3545	3545	85	.0194	3640	3640	3645	---	---	---	1195	None	0095	0095	0100
G-1	3560	3550	3550	35	.0189	3660	3660	3665	---	---	---	1215	None	0100	0100	0115

\*To nearest 0.0005 inch

## PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: IC1 TEST PLATE NUMBER: II

MANDREL: ST 5300 CBM ( ) O-N NOMINAL SIZE: 3/8" (-12)

MAX. DIA. MANDREL: .3538" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: .015 inch/inch

PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .010" MANDREL DIA. +2xSLEEVE THICKNESS: .3738"

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 3/8"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
A-1	3615	3610	3610	50	.0128	3655	3660	3670	--	--	--	1375	None	0050	0050	0050
A-2	3605	3610	3605	35	.0128	3665	3670	3675	--	.0015	.0035	--	None	0060	0060	0070
A-3	3605	3605	3610	55	.0133	3655	3655	3665	25	--	--	1315	None	0050	0050	0055
A-4	3605	3605	3605	75	.0133	3645	3645	3660	--	--	--	1265	None	0040	0040	0055
A-5	3605	3605	3605	45	.0133	3670	3670	3675	--	--	--	1425	None	0065	0065	0070
A-6	3605	3605	3605	80	.0133	3670	3670	3675	--	--	--	1550	None	0065	0065	0070

\*To nearest 0.0005 inch

# PHASE I TASK I MANDREL TAPER DETERMINATION

TEST NUMBER IC2 TEST PLATE NUMBER 11

MANDREL ST 5300 CBM (J) ON NOMINAL SIZE 3/8" (12)

MAX DIA MANDREL .3538" MANDREL MATERIAL H-II-nitrided MANDREL TAPER .030 inch/inch

PULL X PUSH  LUBRICATION Fel Pro 300 (on sleeve)

SLEEVE THICKNESS .010" MANDREL DIA +2xSLEEVE THICKNESS .3738"

TEST MATERIAL Aluminum COMPOSITION 2024-T851 STACK UP 3/8"

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid	Bot			Top	Mid	Bot						Top	Mid	Bot
A-7	3605	3600	3600	80	.0138	3665	3660	3670	---	---	---	1400	None	0060	0060	0070
A-8	3600	3600	3600	50	.0138	3675	3665	3665	20	---	---	1290	None	0075	0065	0065
B-1	3605	3605	3605	45	.0133	3650	3650	3660	---	---	---	1170	None	0045	0045	0055
B-2	3605	3605	3605	40	.0133	3650	3650	3655	---	.0020	.0040	1115	None	0045	0045	0050
B-3	3605	3605	3605	25	.0133	3665	3665	3675	---	---	---	1300	None	0060	0060	0070
B-4	3605	3605	3605	45	.0133	3665	3665	3665	---	---	---	1225	None	0060	0060	0060
B-5	3605	3605	3605	70	.0133	3650	3650	3660	---	---	---	1160	None	0045	0045	0055

\*To nearest 0.0005 inch

PHASE I-TASK I-MANDREL TAPER DETERMINATION

TEST NUMBER: IC3 TEST PLATE NUMBER II

MANDREL: ST 5300 CBM-(J)-O-N NOMINAL SIZE: 3/8" (-12)

MAX. DIA. MANDREL: .3539" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: .045 inch/inch

PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .010" MANDREL DIA. .2x SLEEVE THICKNESS: .3739"

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 3/8"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
B-6	3605	3605	3605	40	.0134	3670	3670	3675	--	--	--	1120	None	0065	0065	0070
B-7	3605	3605	3605	80	.0134	3670	3670	3675	--	--	--	1145	None	0065	0065	0070
C-1	3605	3605	3600	40	.0134	3650	3655	3655	--	--	--	1025	None	0045	0050	0055
C-2	3605	3605	3605	65	.0134	3665	3665	3675	30	.0030"	.0050"	1065	None	0060	0060	0070
C-3	3605	3605	3605	70	.0134	3655	3655	3655	--	--	--	1030	None	0050	0050	0050
C-4	3605	3605	3605	65	.0134	3670	3670	3675	--	--	--	1540	None	0065	0065	0070

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER                      ID1                      TEST PLATE NUMBER                      II                     

MANDREL                      ST 5300 CBM-1 J-O-N                      NOMINAL SIZE                      3/8" (-12)

MAX. DIA MANDREL                      MANDREL MATERIAL:                      H-II-nitrided                      MANDREL TAPER:                     

PULL                      X                      PUSH:                      LUBRICATION:                      Fel Pro 300 (on sleeve)

SLEEVE THICKNESS:                      .010"                      MANDREL DIA. +2xSLEEVE THICKNESS:                      .3738"

TEST MATERIAL:                      Aluminum                      COMPOSITION:                      2024-T851                      STACK UP:                      3/8"

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
E-1	3650	3650	3645	50	.0088	3670	3670	3670	--	--	--	1235	None	0020	0020	0025
E-2	3650	3650	3650	65	.0088	3685	3685	3685	--	.0010	.0030	1275	None	0035	0035	0035
E-3	3655	3655	3660	55	.0083	3685	3685	3690	--	--	--	1260	None	0030	0030	0030
E-4	3650	3655	3655	60	.0083	3670	3675	3680	25	--	--	1045	None	0020	0020	0025
E-5	3655	3655	3655	60	.0083	3685	3685	3690	--	--	--	1200	None	0030	0030	0035
E-6	3655	3655	3655	50	.0083	3685	3685	3690	--	--	--	1190	None	0030	0030	0035

\*To nearest 0.0005 inch

# PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: ID2 TEST PLATE NUMBER: II

MANDREL: ST 5300 CBM(I) ON NOMINAL SIZE: 3/8" (-12)

MAX. DIA. MANDREL: .3538" MANDREL MATERIAL: H-11-nitrided MANDREL TAPER: .030 inch/inch

PULL: X PUSH: LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .010" MANDREL DIA. +2XSLEEVE THICKNESS: .3738"

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 3/8"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid	Bot.
E-7	3655	3650	3650	70	.0088	3670	3670	3670	--	--	--	915	None	0015	0015	0020
E-8	3655	3655	3655	50	.0083	3680	3680	3685	--	--	--	1045	None	0025	0025	0030
F-1	3650	3650	3650	50	.0088	3670	3670	3670	--	--	--	990	None	0020	0020	0020
F-2	3655	3655	3650	80	.0083	3685	3685	3685	35	--	--	1025	None	0030	0030	0030
F-3	3655	3655	3655	60	.0083	3680	3680	3680	--	.0005	.0030	1030	None	0025	0025	0025
F-4	3655	3660	3655	65	.0078	3685	3685	3685	--	--	--	995	None	0030	0025	0030

\* To nearest 0.0005 inch

TEST NUMBER            ID3            TEST PLATE NUMBER            II           

MANDREL            ST 5300 CBM-{} O-N            NOMINAL SIZE            3/8" (-.12)

MAX. DIA. MANDREL            .3539"            MANDREL MATERIAL            H-II-nitrided            MANDREL TAPER            .045 inch/inch

PULL            X            PUSH            LUBRICATION            Fel Pro 300 (on sleeve)

SLEEVE THICKNESS .010" MANDREL DIA. +2xSLEEVE THICKNESS .3739"

TEST MATERIAL \_\_\_\_\_ Aluminum \_\_\_\_\_ COMPOSITION: \_\_\_\_\_ 2024-T851 \_\_\_\_\_ STACK UP: \_\_\_\_\_ 3/8"

[illegible]

To nearest 0.0005 inch



TEST NUMBER	IF2	TEST PLATE NUMBER	11:

MANDREL ST 5300 CBM-1 O-N NOMINAL SIZE 3/8" (.12)

MAX DIA MANDREL 3538" MANDREL MATERIAL H-II-nitrided MANDREL TAPER .030 inch/inch

PULL X PUSH LUBRICATION Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .010" MANDREL DIA. +2xSLEEVE THICKNESS: .3738"

TEST MATERIAL Aluminum COMPOSITION 2024-T851 STACK UP: 1-1/2"

[illegible]

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PHASE I-TASK I-MANDREL TAPER DETERMINATION

TEST NUMBER: IF3 TEST PLATE NUMBER: III

MANDREL: ST 5300 CBM-I (J)-O-N NOMINAL SIZE: 3/8" (.12)

MAX DIA. MANDREL: .3539" MANDREL MATERIAL: H-11-nitrided MANDREL TAPER: .045 inch/inch

PULL: X PUSH:  LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .010" Nom. MANDREL DIA. 2xSLEEVE THICKNESS: .3739"

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/2"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
D-4	3540	3540	3540	30	.0199	3690	3680	3690	15	-	-	2360	None	0150	0140	0150
D-5	3540	3545	3540	-	.0194	3695	3680	3685	-	-	-	2450	None	0155	0135	0145
D-6	3540	3540	3545	-	.0199	3695	3680	3680	-	0030	.0045	2475	None	0155	0140	0135
D-7	3540	3540	3540	-	.0199	3685	3665	3665	-	-	-	2225	None	0145	0125	0125
D-8	3540	3540	3540	-	.0199	3690	3680	3685	-	-	-	2455	None	0155	0140	0145

\*To nearest 0.0005 inch

# PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: IG1 TEST PLATE NUMBER: III

MANDREL: ST 5300 CBM-I J-O-N NOMINAL SIZE: 3/8" (-12)

MAX DIA. MANDREL: .3538" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: .015 inch/inch

PULL: X PUSH:  LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .010" Nom. MANDREL DIA. +2xSLEEVE THICKNESS: .3738"

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/2"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
F-3	3620	3620	3620	-	.0118	3695	3680	3690	-	-	-	2525	None	0075	0060	0070
F-4	3620	3620	3620	25	.0118	3675	3670	3690	10	-	-	2485	None	0055	0050	0070
F-5	3620	3620	3620	-	.0118	3675	3670	3675	-	-	-	2385	None	0055	0050	0055
F-6	3620	3620	3620	-	.0118	3690	3685	3695	-	.0030	.0045	2565	None	0070	0065	0075
F-7	3620	3620	3620	-	.0118	3680	3680	3690	-	-	-	2375	None	0060	0060	0070
F-8	3620	3620	3620	-	.0118	3690	3685	3675	-	-	-	2500	None	0070	0065	0055

\*To nearest 0.0005 inch

# PHASE I-TASK I-MANDREL TAPER DETERMINATION

TEST NUMBER: IG2 TEST PLATE NUMBER: III

MANDREL: ST 5300 CBM-I J-O-N NOMINAL SIZE: 3/8" (12)

MAX. DIA. MANDREL: .3538" MANOREL MATERIAL: H-II-nitrided M/ANDREL TAPER: .030 inch/inch

PULL: X PUSH:        LUBRICATION: Fel Pro 320 (on sleeve)

SLEEVE THICKNESS: .010" MANDREL DIA.: 2xSLEEVE THICKNESS: .3738"

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/2"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
E-6	3620	3620	3620	-	.0188	3680	3665	3680	-	.0030	.0045	1955	None	0060	0045	0060
E-7	3620	3620	3620	-	.0118	3690	3685	3695	-	-	-	2070	None	0070	0065	0075
E-8	3620	3620	3620	-	.0118	3690	3685	3690	-	-	-	1965	None	0070	0065	0070
F-1	3620	3620	3620	45	.0118	3690	3685	3670	20	-	-	1710	None	0070	0065	0050
F-2	3620	3620	3620	-	.0118	3675	3665	3690	-	-	-	1990	None	0055	0045	0070

\*To nearest 0.0005 inch

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/2"

[illegible]

\* To nearest 0.0005 inch

## PHASE I TASK I MANDREL TAPER DETERMINATION

TEST NUMBER III TEST PLATE NUMBER III

MANDREL ST 5300 CBM-1 P-ON NOMINAL SIZE 3/8" (-12)

MAX DIA. MANDREL .3538" MANDREL MATERIAL: H-11 nitrided MANDREL TAPER: .015 inch/inch

PULL: X PUSH: \_\_\_\_\_ LUBRICATION Fel Pro 300 (on sleeve)

SLEEVE THICKNESS .010" Nom. MANDREL DIA. +2xSLEEVE THICKNESS .3738"

TEST MATERIAL: Aluminum COMPOSITION 2024-T851\* STACK UP: 1-1/2"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out			Returned hole expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.					Top	Mid	Bot.	Top	Mid	Bot.
G-1	3650	3650	3650	16	.0088	3700	3695	3700	10	-	-	1750	None			0050	0045	0050
G-2	3650	3650	3650	-	.0088	3700	3695	3705	-	-	-	2060	None			0050	0045	0050
G-3	3650	3650	3650	-	.0088	3685	3685	3680	-	-	-	1165	None			0035	0035	0035
G-4	3650	3650	3650	-	.0088	3685	3680	3685	-	-	-	1380	None			0035	0030	0035
G-5	3650	3650	3650	-	.0088	3690	3685	3685	-	.0020	.0045	1240	None			0040	0035	0035

\*To nearest 0.0005 inch

# PHASE I-TASK I-M: DREL TAPER DETERMINATION

TEST NUMBER: IH2 TEST PLATE NUMBER: III

MANDREL: ST 5300 CBM-( )-O-N NOMINAL SIZE: 3/8" (.12)

MAX. DIA. MANDREL: .3538" MANDREL MATERIAL: H11-nitrided MANDREL TAPER: .030 inch/inch

PULL: X PUSH: --- LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .010" Nom. MANDREL DIA. +2xSLEEVE THICKNESS: .3738"

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/2"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
G-6	3650	3650	3650	20	.0088	3705	3695	3700	10	---	---	---	None	0055	0045	0050
G-7	3650	3650	3650	---	.0088	3700	3680	3685	---	---	---	1240	None	0050	0030	0035
G-8	3650	3650	3650	---	.0088	3685	3680	3685	---	.0015	.0095	1160	None	0035	0030	0035
H-1	3650	3650	3650	16	.0088	3685	3685	3705	---	---	---	1360	None	0035	0035	0055
H-2	3650	3650	3650	---	.0088	3700	3695	3685	---	---	---	1195	None	0050	0045	0035
H-3	3650	3650	3650	---	.0088	3700	3695	3685	---	---	---	1195	None	0050	0045	0035

\*To nearest 0.0005 inch

# PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: IH3 TEST PLATE NUMBER: III

MANDREL: ST 5300 CBM-( )-O-N NOMINAL SIZE: 3/8" (-12)

MAX. DIA. MANDREL: .3539" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: .045 inch/inch

PULL: X PUSH: LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .010" Nom. MANDREL DIA. +2xSLEEVE THICKNESS: .3739"

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/2"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
H-4	3650	3650	3650	40	.0089	3690	3680	3685	15	.0015	--	975	None	0040	0030	0035
H-5	3650	3650	3650	--	.0089	3685	3680	3685	--	--	.0035	930	None	0035	0030	0035
H-6	3650	3650	3650	--	.0089	3705	3695	3700	--	--	--	1150	None	0055	0045	0055
H-7	3650	3650	3650	--	.0089	3685	3680	3685	--	--	--	925	None	0035	0030	0035
H-8	3650	3650	3650	--	.0089	3700	3695	3700	--	--	--	1200	None	0050	0045	0050

\*To nearest 0.0005 inch

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# PHASE I-TASK I-MANDREL TAPER DETERMINATION

TEST NUMBER: IJ2 TEST PLATE NUMBER: V

MANDREL ST 5300 CRM-( )-ON NOMINAL SIZE: 3/4" (.24)

MAX DIA. MANDREL: .7165" MANDREL MATERIAL: H11-miridid MANDREL TAPER: .030 inch/inch

PULL: X PUSH: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .015" MANDREL DIA. 2xSLEEVE THICKNESS .7465"

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/8"

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid	Bot.			Top	Mid	Bot.						Top	Mid	Bot.
C-4	.7135	.7130	.7130	-	.0335	.7360	.7335	.7365	-	.0025	.0070	9.960	-	.0225	.0205	.0235
D-1	.7130	.7130	.7130	-	.0335	.7350	.7320	.7370	-	-	-	10.070	-	.0220	.0190	.0240
D-2	.7135	.7130	.7130	8-10	.0335	.7360	.7315	.7370	5	-	-	10.100	-	.0225	.0185	.0240
D-3	.7135	.7130	.7130	-	.0335	.7370	.7330	.7365	-	-	-	10.180	-	.0235	.0200	.0235
D-4	.7135	.7135	.7130	-	.0330	.7365	.7330	.7360	-	-	-	10.330	-	.0230	.0195	.0230

\*To nearest 0.0005 inch

TEST NUMBER: IJ3 TEST PLATE NUMBER: VI

MANDREL: ST 5300 CBM-1 O.N. 3/4" (24)

MANDREL MATERIAL: H-11-nitrided MANDREL TAPER: .045 inch/inch

PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

MAX. DIA. MANDREL: .7165"

SLEEVE THICKNESS: .015" MANDREL DIA. +2xSLEEVE THICKNESS: .7465"

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/8"

[illegible]

To nearest 0.0005 inch

## PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: IK1 TEST PLATE NUMBER: IV

MANDREL: ST 5300 CBM-1 JON NOMINAL SIZE: 3/4" (-24)

MAX. DIA. MANDREL: .7163" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: .020 inch/inch

PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .015" MANDREL DIA. +2xSLEEVE THICKNESS: .7463"

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 2.50"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
A-1	7205	7200	7195	120	.0263	7390	7340	7390	—	—	—	13,020	None	0185	0140	0195
A-2	7205	7200	7195	60	.0263	7390	7350	7395	—	—	—	11,900	None	0185	0150	0200
A-3	7205	7200	7195	60	.0263	7395	7345	7420	25	.0050	.0080	11,440	None	0190	0145	0225
A-4	7205	7200	7195	70	.0263	7390	7340	7395	—	—	—	11,260	None	0185	0140	0200
B-1	7205	7200	7195	40	.0263	7380	7335	7385	—	—	—	11,020	None	0175	0135	0190
B-2	7205	7200	7195	40	.0263	7390	7340	7390	—	—	—	13,080	None	0185	0140	0195

\*To nearest 0.0005 inch

# PHASE I-TASK I-MANDREL TAPER DETERMINATION

TEST NUMBER: IK2 TEST PLATE NUMBER: V

MANDREL: ST 5300 CBM-1 J-O-N NOMINAL SIZE 3/4" (-24)

MAX O/A, MANDREL: .7165" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: .030 inch/inch

PULL: X PUSH: Fe/ Pro 300 (on sleeve/

LUBRICATION: Fe/ Pro 300 (on sleeve/

SLEEVE THICKNESS: .015" MANDREL DIA. +2xSLEEVE THICKNESS: .7465"

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/8"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
A-1	7195	7200	7190	-	.0265	7360	7330	7360	-	-	-	8270	-	0165	0130	0170
A-2	7195	7195	7195	8-10	.0270	7370	7345	7370	5	-	-	8270	-	0175	0150	0175
A-3	7195	7195	7195	-	.0270	7365	7340	7370	-	-	-	8260	-	0170	0145	0175
A-4	7195	7195	7190	-	.0270	7365	7330	7370	-	-	-	7860	-	0170	0135	0160
B-1	7195	7195	7195	-	.0270	7370	7335	7380	-	.0025	.0065	7800	-	0175	0140	0185
B-2	7195	7195	7195	8-10	.0270	7380	7340	7380	-	-	-	7760	-	0185	0145	0185

\*To nearest 0.0005 inch

# PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: IK3 TEST PLATE NUMBER: VI

MANDREL: ST 5300 CBM (10N) NOMINAL SIZE: 3/4" (-24)

MAX. DIA. MANDREL: 7165 MANDREL MATERIAL: HJ2 nitrided MANDREL TAPER: .045 inch/inch

PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .015 MANDREL DIA. 2X SLEEVE THICKNESS: 7465

TEST MATERIAL: Aluminum COMPOSITION: 2024-T351 STACK UP: 1-1/8"

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (Table 1)	Size after CW*			Finish after CW	Usert clearance of hole	Usert exit of hole	Force required for mandrel	Sleeve thru out	Retain hole expansion (Table 1)	
	Top	Mid.	Bot			Top	Mid	Bot						Top	Bot
A-1	7210	7215	7195	-	.0250	7370	7335	7360	-	-	-	7500	-	0160	0155
A-2	7195	7195	7190	-	.0270	7370	7340	7365	-	-	-	6750	-	0175	0175
A-3	7195	7195	7190	5-10	.0270	7370	7340	7365	5	.0025"	.0090"	6600	-	0175	0175
A-4	7200	7215	7190	-	.0250	7365	7335	7360	-	-	-	6320	-	0165	0170
B-1	7195	7200	7195	-	.0265	7375	7345	7385	-	-	-	6080	-	0180	0190
B-2	7195	7195	7195	-	.0270	7380	7340	7375	-	-	-	6200	-	0185	0180

\*To nearest 0.0005 inch

PHASE I-TASK I-MANDREL TAPER DETERMINATION

TEST NUMBER: IL1 TEST PLATE NUMBER: IV  
 MANDREL: ST 5300 CBM-1 O-N NOMINAL SIZE: 3/4" (-24)  
 MAX. DIA. MANDREL: .7163" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: .020 inch/inch  
 PULL: X PUSH:      LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .015" MANDREL DIA. 2xSLEEVE THICKNESS: .7463"

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 2.50"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
C-4	7250	7250	7250	40	.0213	7395	7350	7380	-	-	-	10,200	.0005" typ	0145	0100	0130
D-1	7250	7250	7250	30	.0213	7400	7340	7380	-	-	-	9,440	.0005" typ	0150	0090	0130
D-2	7250	7250	7245	30	.0213	7405	7335	7385	-	-	-	8,740	.0005" typ	0155	0085	0140
D-3	7250	7250	7245	40	.0213	7400	7345	7385	15	.0035	.0075	-	.0005" typ	0150	0085	0140
D-4	7250	7245	7245	30	.0218	7385	7335	7380	-	-	-	-	.0005" typ	0135	0050	0135

\*To nearest 0.0005 inch

## PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER 112 TEST PLATE NUMBER V

MANDREL ST 5300 CBM (J)-N NOMINAL SIZE 3/4" (24)

MAX DIA MANDREL .7165" MANDREL MATERIAL H-II-nitrided MANDREL TAPER .030 inch/inch

PULL X PUSH  LUBRICATION Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .015" MANDREL DIA. + 2 x SLEEVE THICKNESS .7465"

TEST MATERIAL Aluminum COMPOSITION 2024-T851 STACK UP 1-1/8"

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
B-3	7240	7240	7240	-	.0225	7380	7350	7380	-	-	-	6440	-	0140	0110	0140
B-4	7240	7240	7235	-	.0225	7375	7340	7380	-	-	-	6260	-	0135	0100	0145
C-1	7240	7235	7235	-	.0230	7385	7355	7385	-	-	-	6160	-	0145	0125	0150
C-2	7240	7235	7235	8-10	.0230	7380	7355	7385	5	.0015	.0055	6150	-	0140	0120	0150
C-3	7240	7240	7235	-	.0225	7385	7350	7385	-	-	-	6250	-	0145	0110	0150

\*To nearest 0.0005 inch

PHASE I-TASK I-MANDREL TAPER DETERMINATION

TEST NUMBER: IL3 TEST PLATE NUMBER: VI

MANDREL: ST 5300 CBM-I ON 3/4" (-12)

MAX DIA. MANDREL: .7165" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: 0.45 inch/inch

PULL: X PUSH: LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .015" MANDREL DIA. +2xSLEEVE THICKNESS: .7465

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/8"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid	Bot			Top	Mid	Bot						Top	Mid	Bot
B-3	7240	7240	7240	20	.0225	7380	7350	7365	10	-	-	5240	-	0140	0110	0125
B-4	7240	7240	7240	-	.0225	7380	7350	7370	-	-	-	5300	-	0140	0110	0130
C-1	7235	7240	7235	-	.0225	7370	7345	7365	-	.0020	.0065	5220	-	0145	0105	0130
C-2	7240	7240	7240	-	.0225	7375	7345	7370	-	-	-	5360	-	0135	0105	0130
C-3	7235	7235	7235	-	.0230	7380	7.50	7365	-	-	-	5290	-	0145	0115	0130

\* To nearest 0.0005 inch

# PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1A1T TEST PLATE NUMBER: VII

MANDREL: ST 5300 CBM (-) O-N NOMINAL SIZE: 3/8 inch (-12)

MAX. DIA. MANDREL 0.3538 inch MANDREL MATERIAL: H-II nitrided MANDREL TAPER: 0.015 inch/inch

PULL: X PUSH: Fel Pro 300 (on sleeve) LUBRICATION:

SLEEVE THICKNESS: 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.3738 inch

TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 3/8 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
A1	3555	3555	3555	—	.0168	3660	3650	3660	—	—	—	2190	.0010	0105	0095	0105
B1	3555	3555	3555	40	.0166	3660	3650	3660	20	—	—	2190	.0010	0105	0095	0105
C1	3555	3555	3555	—	.0165	3660	3655	3670	—	.0045	.0050	2270	.0010	0105	0100	0115
D1	3555	3555	3555	—	.0165	3660	3650	3665	—	—	—	2275	.0010	0105	0095	0110
E1	3555	3555	3555	—	.0165	3645	3640	3655	—	—	—	2235	.0010	0090	0085	0100

\* To nearest 0.0005 inch

1 Mandrel diameter progressively reduced to 0.3531 inch in 5 holes

TEST NUMBER 1A2T TEST PLATE NUMBER VII

MANDREL ST 5300 CBM-110-N NOMINAL SIZE 3/8 inch (12)

MAX DIA MANDREL 0.3538 inch MANDREL MATERIAL H-II-nitrided MANDREL TAPER 0.030 inch/inch

PULL: X PUSH: \_\_\_\_\_ LUBRICATION Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: 0.010 inch MANDREL DIA. 2 x SLEEVE THICKNESS: 0.3738 inch

TEST MATERIAL: Titanium COMPOSITION 6Al-4V STACK UP: 3/8 inch

[illegible]

To nearest 0.0005 inch

**1** Mandrel diameter progressively reduced to 0.3531 inch in 5 holes

## PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1A3T TEST PLATE NUMBER: VII

MANDREL: ST 5300 CBM-(-)-O-N NOMINAL SIZE: 3/8 inch (-12)

MAX. DIA. MANDREL: 0.3539 inch MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: 0.045 inch/inch

PULL: X PUSH: Fel Pro 300 (on sleeve)

LUBRICATION:

SLEEVE THICKNESS: 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.3739 inch

TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 3/8 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
C2	3555	3555	3555	—	.0172	3660	3650	3660	—	—	—	1635	.0010	0.105	0095	0105
D2	3555	3555	3555	—	.0172	3660	3655	3660	—	—	—	1425	.0010	0105	0100	0105
E2	3555	3555	3555	30	.0172	3650	3650	3665	12	—	—	1440	.0010	0095	0095	0110
F2	3555	3555	3555	—	.0172	3660	3650	3660	—	—	—	1400	.0010	0105	0095	0105
G2	3555	3555	3555	—	.0172	3660	3650	3660	—	0.005	0.0054	1435	.0010	0105	0095	0105

\* To nearest 0.0005 inch

 Mandrel diameter progressively reduced to 0.3537 inch in 5 holes

TEST NUMBER 181T TEST PLATE NUMBER VII

MANDREL ST 5300 CBM-( ) O-N NOMINAL SIZE 3/8 inch (-12)

MAX DIA MANDREL 0.3531 inch MANDREL MATERIAL H-11-nitrided MANDREL TAPER: 0.015 inch/inch

PULL X PUSH \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS 0.010 inch MANDREL DIA + 2 x SLEEVE THICKNESS: 0.3731 inch

TEST MATERIAL Titanium COMPOSITION 6Al-4V STACK UP 3/8 inch

[illegible]

To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER 1B2T TEST PLATE NUMBER VII  
 MANDREL ST 5300 CBM-I (-) O-N NOMINAL SIZE 3/8 inch (-.12)  
 MAX DIA. MANDREL 0.3531 inch MANDREL MATERIAL H-II-nitrided MANDREL TAPER: 0.030 inch/inch  
 PULL: X PUSH: LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.3731 inch

TEST MATERIAL Titanium COMPOSITION: 6Al-4V STACK UP: 3/8 inch

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole expansion (calc.)		
	Top	Mid	Bot			Top	Mid	Bot						Top	Mid	Bot
F3	3600	3600	3600	-	.0121	3660	3660	3665	-	-	-	1460	.0005	0060	0060	0065
G3	3600	3600	3600	-	.0121	3600	3655	3665	-	.0021	.0025	1400	.0005	0060	0055	0065
H3	3600	3600	3600	-	.0121	3665	3660	3670	-	-	-	1420	.0005	0065	0060	0070
A4	3600	3600	3600	-	.0121	3665	3660	3665	-	-	-	1390	.0005	0065	0060	0065
B4	3600	3600	3600	25	.0121	3665	3660	3665	12	-	-	1440	.0005	0065	0060	0065

\* To nearest 0.0005 inch

TEST NUMBER: 183T TEST PLATE NUMBER VII

MANDREL: ST 5300 CBM-I (-) -N NOMINAL SIZE 3/8 inch (-12)

MAX DIA. MANDREL 0.3537 inch MANDREL MATERIAL: H-II-nitrided MANDREL TAPER 0.045 inch/inch

PULL X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE  $\phi$  THICKNESS 0.010 inch MANDREL DIA. + 2  $\times$  SLEEVE THICKNESS 0.3737 inch

TEST MATERIAL Titanium COMPOSITION: 6Al-4V STACK UP: 3/8 inch

[illegible]

For every 1000, 1 inch

# PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER 1C1T TEST PLATE NUMBER VII  
 MANDREL: ST 5300 CBM-4 J-O-N NOMINAL SIZE 3/8 inch (1-12)  
 MAX DIA. MANDREL: 0.3531 inch MANDREL MATERIAL H-II-nitrided MANDREL TAPER 0.015 inch/inch  
 PULL X PUSH      LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.3731 inch

TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 3/8 inch

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid	Bot.			Top	Mid	Bot.						Top	Mid	Bot.
A5	3660	3660	3660	-	.0071	3685	3685	3690	-	-	-	1440	None	0025	0025	0030
P5	3660	3660	3660	20	.0071	3680	3680	3685	10	.0020	.0025	1320	None	0020	0020	0025
C5	3660	3660	3660	-	.0071	3685	3685	3690	-	-	-	1375	None	0025	0025	0030
D5	3660	3660	3660	-	.0071	3685	3685	3690	-	-	-	1285	None	0025	0025	0030
E5	3660	3660	3660	-	.0071	3685	3685	3690	-	-	-	1300	None	0025	0025	0030

\* To nearest 0.0005 inch

TEST NUMBER 1C2T TEST PLATE NUMBER VII

MANDREL	ST 5300 CBM-1 )-O-N	NOMINAL SIZE	3/8 inch (-12)

MAX DIA MANDREL 0.3531 inch  
MANDREL MATERIAL H-II-nitrided  
MANDREL TAPER 0.030 inch/inch

PULL            X            PUSH:             
LUBRICATION:             
Fe/Pro 300 (on sleeve)           

SLEEVE THICKNESS: 0.010 inch

TEST MATERIAL Titanium COMPOSITION: 6Al-4V STACK UP: 3/8 inch

[illegible]

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## PHASE I - TASK I. MANDREL TAPER DETERMINATION

TEST NUMBER 1C3T TEST PLATE NUMBER VII

MANDREL: ST 5300 CBM (-) O-N NOMINAL SIZE 3/8 inch (-12)

MAX DIA. MANDREL 0.3537 inch MANDREL MATERIAL H-II-nitrided MANDREL TAPER 0.045 inch/inch

PULL X PUSH      LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.3737 inch

TEST MATERIAL: Titanium COMPOSITION 6Al-4V STACK UP: 3/8 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
C6	3660	3660	3660	-	.0077	3685	3685	3690	-	-	-	1040	None	0025	0025	0030
D6	3660	3660	3660	-	.0077	3690	3685	3690	-	-	-	1030	None	0030	0025	0030
E6	3660	3660	3660	20	.0077	3685	3685	3690	10	.0023	.0027	1000	None	0025	0025	0030
F6	3660	3660	3660	-	.0077	3690	3685	3690	-	-	-	985	None	0030	0025	0030
G6	3660	3660	3660	-	.0077	3685	3685	3690	-	-	-	1020	None	0025	0025	0030

\*To nearest 0.0005 inch

TEST NUMBER: 1D1T TEST PLATE NUMBER: VIII

MANDREL: ST 5300 CBM-( J-O-N NOMINAL SIZE: 3/8 inch (-.12)

MAX. DIA. MANDREL: 0.3538 inch MANDREL MATERIAL: H-11-nitrided MANDREL TAPER: 0.015 inch/inch

PULL: X PUSH: LUBRICATION: Fel Pro 300 (on sleeve)



MAX DIA MANDREL : 0.3538 inch  
MANDREL MATERIAL : H-II-nitrided  
MANDREL TAPER: 0.015 inch/inch

**PULL:** ☒ **PUSH:** ☐

**LUBRICATION:** ☐ **Fel Pro 300 (on sleeve)**

SLEEVE THICKNESS: 0.010 inch

TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 1-1/2 inches

[illegible]

\* To nearest 0.0005 inch

TEST NUMBER: 1D2T TEST PLATE NUMBER: VIII

MANDREL: ST 5300 CBM-( )O-N NOMINAL SIZE: 3/8 inch (-12)

MAX. DIA. MANDREL: 0.3531 inch MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: 0.030 inch/inch

PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.3731 inch

TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 1-1/2 inches

SLEEVE THICKNESS: 0.010 inch

TEST MATERIAL	Titanium	COMPOSITION:	6Al-4V	STACK UP:	1-1/2 inches
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[illegible]

To nearest 0.0005 inch

**Mandrel diameter progressively reduced to 0.3525 inch in 5 holes**



## PHASE I - TASK 1 MANDREL TAPER DETERMINATION

TEST NUMBER 1E1T TEST PLATE NUMBER VIII

MANDREL ST 5300 CBM (-) O-N NOMINAL SIZE 3/8 inch (-12)

MAX DIA MANDREL 0.3538 inch MANDREL MATERIAL H-II-nitrided MANDREL TAPER 0.015 inch/inch

PULL X PUSH      LUBRICATION Fel Pro 300 (on sleeve)

SLEEVE THICKNESS 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS 0.3738 inch

TEST MATERIAL Titanium COMPOSITION 6Al-4V STACK UP: 1-1/2 inches

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
C1	3605	3605	3605	-	.0115	3645	3640	3650	-	-	-	7320	.0005	0040	0035	0050
C2	3605	3605	3605	-	.0110	3650	3640	3655	-	-	.0045	7520	.0005	0045	0035	0055
C3	3605	3605	3605	20	.0108	3555	3640	3655	10	.0035	-	5540	.0005	0050	0035	0050
C4	3605	3605	3605	-	.0108	3650	3630	3650	-	-	-	4220	.0005	0045	0025	0045

\* To nearest 0.0005 inch

▷ Mandrel diameter progressively reduced to 0.3523 inch in 4 holes

PHASE I—TASK I—MANDREL TAPER DETERMINATION

TEST NUMBER: 1E2T TEST PLATE NUMBER: VIII  
 MANDREL: ST 5300 CBM-I (J)-N NOMINAL SIZE: 3/8 inch (12)  
 MAX. DIA. MANDREL: 0.3520 inch MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: 0.030 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.3720 inch

TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 1-1/2 inches

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
C6	3605	3605	3600	—	.0105	3650	3640	3660	—	—	—	3380	.0005	0045	0035	0060
C7	3605	3605	3605	—	.0105	3645	3635	3660	—	.0038	—	3180	.0005	0040	0030	0055
C8	3605	3600	3605	—	.0105	3645	3640	3660	—	—	.0045	3300	.0005	0040	0040	0055
D1	3605	3605	3605	—	.0105	3645	3640	3660	—	—	—	3940	.0005	0040	0035	0055
D2	3605	3605	3605	18	.0105	3650	3640	3665	10	—	—	3400	.0005	0045	0035	0060

\*To nearest 0.0005 inch


PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER 1E3T TEST PLATE NUMBER VIII  
 MANDREL ST 5300 CBM (-) ON NOMINAL SIZE 3/8 inch (-12)  
 MAX DIA. MANDREL 0.3539 inch MANDREL MATERIAL H-II-nitrided MANDREL TAPER 0.045 inch/inch  
 PULL X PUSH \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS 0.3739 inch

TEST MATERIAL Titanium COMPOSITION: 6Al-4V STAGI UP: 1-1/2 inches

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
D3	3605	3605	3605	-	.0119	3660	3645	3660	-	-	-	3280	.0005	0055	0040	0055
D4	3605	3605	3605	-	.0119	3665	3640	3660	-	.0038	-	2760	.0005	0050	0035	0055
D5	3605	3600	3600	-	.0119	3650	3640	3665	-	-	-	3060	.0005	0045	0040	0065
D6	3605	3605	3605	15	.0117	3650	3640	3665	8	-	.0045	3120	.0005	0045	0040	0060
D7	3605	3605	3605	-	.0114	3650	3640	3660	-	-	-	2920	.0005	0045	0040	0055
D8	3605	3605	3605	-	.0122	3650	3640	3660	-	-	-	3450	.0005	0045	0040	0055

\* To nearest 0.0005 inch  Mandrel diameter progressively reduced to 0.3529 inch in 5 holes.  
 AISI 9260 mandrel used for hole D8. Maximum diameter = 0.3537 inch.

PHASE I TASK I MANDREL TAPER DETERMINATION

TEST NUMBER 1F11 TEST PLATE NUMBER VIII  
 MANDREL ST 5300 CBM-I (J) ON NOMINAL SIZE 3/8 inch (.12)  
 MAX DIA MANDREL 0.3623 inch MANDREL MATERIAL H-II nitrided MANDREL TAPER 0.015 inch/inch  
 PULL X PUSH \_\_\_\_\_ LUBRICATION Fel-Pro 300 (on sleeve)

SLEEVE THICKNESS 0.010 inch MANDREL DIA 2 x SLEEVE THICKNESS 0.3723 inch

TEST MATERIAL Titanium COMPOSITION 6Al-4V STACK UP 1-1/2 inches

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole expansion (calc.)		
	Top	Mid	Bot			Top	Mid	Bot						Top	Mid	Bot
E1	3655	3655	3655	-	.0068	3660	3660	3665	-	-	-	5340	None	0005	0005	0010
E2	3655	3655	3660	18	.0068	3660	3650	3670	10	.0024	.0032	4260	None	0005	0005	0010
E3	3655	3655	3655	-	.0068	3660	3660	3670	-	-	-	4800	None	0005	0005	0015
E4	3660	3655	3655	-	.0068	3675	3660	3675	-	-	-	3500	None	0015	0005	0020
E5	3655	3655	3655	-	.0068	3670	3665	3675	-	-	-	3400	None	0015	0010	0020

\*To nearest 0.0005 inch

## PHASE I TASK I MANDREL TAPER DETERMINATION

TEST NUMBER 172 TEST PLATE NUMBER VIII

MANDREL ST 5300 CBM-I-ION NOMINAL SIZE 3/8 inch (.12)

MAX. DIA MANDREL 0.3520 inch MANDREL MATERIAL H-II-nitrided MANDREL TAPER: 0.030 inch/inch

PULL X PUSH  LUBRICATION Fel Pro 300 (on sleeve)

SLEEVE THICKNESS 0.010 inch MANDREL DIA 2 x SLEEVE THICKNESS 0.3720 inch

TEST MATERIAL Titanium COMPOSITION 6Al-4V STACK UP: 1-1/2 inches

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
E6	3660	3655	3655	—	.0065	3680	3670	3685	—	—	—	1630	None	0020	0015	0030
E7	3655	3655	3655	—	.0065	3680	3675	3685	—	.0025	—	1600	None	0025	0020	0030
E8	3655	3655	3650	15	.0065	3680	3570	3685	8	—	.0030	1495	None	0025	0015	0035
F1	3655	3655	3655	—	.0065	3665	3665	3670	—	—	—	1925	None	0010	0010	0015
F2	3655	3655	3655	—	.0065	3665	3665	3670	—	—	—	1910	None	0010	0010	0015

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER 1F3T TEST PLATE NUMBER VIII

MANDREL ST 5300 CBM-I (ION) NOMINAL SIZE 3/8 inch (12)

MAX DIA. MANDREL 0.3537 inch MANDREL MATERIAL H II nitrided MANDREL TAPER 0.045 inch/inch

PULL X PUSH --- LUBRICATION For Pro 400 (on sleeve)

SLEEVE THICKNESS 0.010 inch MANDREL DIA + 2 x SLEEVE THICKNESS 0.3737 inch

TEST MATERIAL Titanium COMPOSITION 6Al-4V STACK UP 1.12 inches

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thickness		Retained hole expansion (calc.)	
	Top	Mid	Bot			Top	Mid	Bot					Top	Bot	Top	Bot
F3	3655	3655	3655	—	.0082	3675	3670	3685	—	—	—	2000	None	0020	0015	0030
F4	3655	3655	3655	—	.0082	3675	3670	3685	—	—	—	2220	None	0020	0015	0030
F5	3655	3655	3655	20	.0082	3680	3675	3690	12	—	—	2040	None	0025	0020	0035
F6	3655	3655	3655	—	.0082	3680	3675	3690	—	—	—	2000	None	0025	0020	0035
F7	3655	3655	3655	—	.0082	3680	3670	3690	—	.0025	.0035	2040	None	0025	0015	0035

\*To nearest 0.0005 inch

TEST NUMBER	1G1T	TEST PLATE NUMBER	IX
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MANDREL: ST 5300 CBM-1 (10-N) NOMINAL SIZE: 3/4 inch (-24)

MAX DIA. MANDREL: 0.7158 inch MANDREL MATERIAL: H-11-nitrided MANDREL TAPER: 0.020 inch/inch

DRILL: X DISC: Lubrication: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: 0.015 inch  
MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.7458 inch

TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 2 inches

[illegible]

To nearest 0.0005 inch

11	Mandrel progressively reduced to 0.7150 inch in 4 holes
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TEST NUMBER: 1G2T  
TEST PLACE: JOHNSON  
IX

NO. HOLES	ST 5300 CBM-1	( ) ON	SQUARE SIZE	3 x 4 inch (24)	
DRILL BIT NO.	07158 inch		H-IH bitruded		0.030 inch dia

X  
 X  
 PUBLICATION  
 Tel: 09-300 00 00 (ext. 101)  
 (6 days a week)

SLEEVE THICKNESS: 0.015 inch

TEST MATERIAL	Titanium	6Al-4V	2 inch
		COMPOSITION	STACK UP:

[illegible]

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER 1G3T TEST PLATE NUMBER IX

MANDREL ST 5300 CBM-1 J-O-N NOMINAL SIZE 3/4 inch (-12)

MAX DIA. MANDREL 0.7148 inch MANDREL MATERIAL H-II-nitrided MANDREL TAPER 0.045 inch/inch

PULL X PUSH LUBRICATION Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: 0.015 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.7448 inch

TEST MATERIAL Titanium COMPOSITION 6Al-4V STACK UP 2 inch

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid	Bot.						Top	Mid.	Bot.
C3	7140	7140	7140	-	.0288	7295	7275	7335	-	-	-	14,500	.001	0155	0135	0195
C4	7140	7140	7140	-	.0283	7295	7275	7335	-	-	-	12,600	.001	0155	0135	0195
D1	7140	7140	7140	-	.0282	7295	7275	7335	-	.0065	.0090	14,100	.001	0155	0135	0195
D2	7140	7140	7140	40	.0282	7295	7275	7335	18	-	-	14,000	.001	0155	0135	0195
D3	7140	7140	7140	-	.0280	7295	7275	7335	-	-	-	13,600	.001	0155	0135	0195

\* To nearest 0.0005 inch

▷ Mandrel diameter progressively reduced to 0.7140 inch in 5 holes.

TEST NUMBER 1H1T TEST PLATE NUMBER X

MANDREL ST 5300 CBM-I J-O-N NOMINAL SIZE 3/4 inch (-24)

MAX DIA. MANDREL 0.7158 inch MANDREL MATERIAL H-II-nitrided MANDREL TAPER 0.020 inch/inch

PULL X PUSH \_\_\_\_\_ LUBRICATION Fel Pro 300 (on sleeve)

SLEEVE THICKNESS 0.015 inch MANDREL DIA. + 2 x SLEEVE THICKNESS 0.7458 inch

TEST MATERIAL Titanium COMPOSITION 6Al-4V STACK UP 2 inch

[illegible]

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**2 inch**

\* To nearest 0.0005 inch

TEST NUMBER: 1H3T TEST PLATE NUMBER: X X

MANDREL: ST 5300 CBM-I O-N NOMINAL SIZE: 3/4 inch (-24)

MAX DIA. MANDREL: 0.7154 inch MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: 0.045 inch/inch

X

PULL: \_\_\_\_\_ PUSH: \_\_\_\_\_

TURBIDICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS:  $\frac{0.015 \text{ inch}}{0.7454 \text{ inch}}$  MANDREL DIA. + 2 x SLEEVE THICKNESS:

TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 2 inch

[illegible]

To nearest 0.0005 inch

Mandrel diameter progressively reduced to .7151 inch in 5 holes.

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER 1J1T TEST PLATE NUMBER: XI

MANDREL ST 5300 CBM-I J-O-N NOMINAL SIZE: 3/4 inch (.24)

MAX. DIA. MANDREL: 0.7164 inch MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: 0.020 inch/inch

PULL X PUSH: LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: 0.015 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.7464 inch

TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 2 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
A1	7250	7250	7250	-	.0194	7340	7320	7345	-	-	-	15,700	.001	0090	0070	0095
A2	7250	7250	7250	-	.0188	7335	7320	7345	-	.0035	.0125	11,800	.001	0085	0070	0095
A3	7250	7245	7245	-	.0188	7330	7320	7345	-	-	-	15,300	.001	0080	0070	0095
A4	7250	7250	7250	-	.0188	7330	0320	7345	-	-	-	15,600	.001	0080	0070	0095
B1	7250	7245	7250	45	.0188	7330	7320	7355	20	-	-	11,900	.001	0080	0070	0105

\*To nearest 0.0005 inch

▷ Mandrel diameter reduced to .7158 inch in first hole.

TEST NUMBER	1J2T	TEST PLATE NUMBER	XI
MANDREL	ST 5300 CBM-I	J-O-N	NOMINAL SIZE 3/4 inch (-24)
MANDREL DIA.	0.7158 inch	MANDREL MATERIAL	H-II-nitrided
MANDREL DIA.	0.7158 inch	MANDREL TAPER	0.030 inch/inch
PULL	X	PUSH	
		LUBRICATION	Fel Pro 300 (on sleeve)
SLEEVE THICKNESS	0.015 inch	MANDREL DIA.	+ 2 x SLEEVE THICKNESS: 0.7458 inch
TEST MATERIAL	Titanium	COMPOSITION	6Al-4V
		STACK UP	2 inch

[illegible]

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## PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1J3T TEST PLATE NUMBER: XI

MANDREL: ST 5300 CBM-( )-ON NOMINAL SIZE: 3/4 inch

MAX DIA. MANDREL: 0.7162 inch MANDREL MATERIAL: H-11-nitrided MANDREL TAPER: 0.045 inch/inch

PULL: X PUSH: Fel Pro 300 (on sleeve) LUBRICATION:

SLEEVE THICKNESS: 0.015 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.7462 inch

TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 2 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upsert entrance of hole	Upsert exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
C4	7250	7250	7250	-	.0192	7355	7315	7345	-	-	-	8300	.001	0085	0065	0095
D1	7250	7250	7245	-	.0184	7335	7315	7345	-	.0035	.0135	8500	.001	0085	0065	0010
D2	7250	7245	7245	30	.0183	7335	7320	7355	18	-	-	9800	.001	0085	0075	0105
D3	7245	7245	7245	-	.0182	7335	7315	7355	-	-	-	8200	.001	0085	0065	0105
D4	7250	7245	7245	-	.0185	7335	7315	7345	-	-	-	8700	.001	0085	0065	0100

\*To nearest 0.0005 inch

TEST NUMBER:	1A1S	TEST PLATE NUMBER:	XII
MANDREL:	Push (Design per BAC 5972)	NOMINAL SIZE:	3/8 inch
MAX. DIA. MANDREL:	0.3580 inch	MANDREL MATERIAL:	Carboloy 883 (GE)
MANDREL TAPER:	0.015 inch/inch	LUBRICATION:	Fel Pro 300
TEST MATERIAL:	300 'M' Steel (280/300 ksi)	STACK UP:	3/8 inch

[illegible]

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TEST NUMBER:	1A2S	TEST PLATE NUMBER:	XII
MANDREL:	Push (Design per BAC 5972)	NOMINAL SIZE:	3/8 inch
MAX. DIA. MANDREL:	0.3580 inch	MANDREL MATERIAL:	Carboloy 883 (GE)
MANDREL TAPER:	0.030 inch/inch	LUBRICATION:	Fel Pro 300
TEST MATERIAL:	300 'M' Steel (280/300 ksi)	STACK UP:	3/8 inch

[illegible]

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PHASE I - TASK 1 - MANDREL TAPER DETERMINATION

TEST NUMBER: 1A3S TEST PLATE NUMBER: X11

MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/8 inch

MAX. DIA. MANDREL: 0.3580 inch MANDREL MATERIAL: Carboloy 883 (GE)

MANDREL TAPER: 0.045 inch/inch LUBRICATION: Fel Pro 300

TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 3/8 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
B3	3445	3445	3455	-	.0125	3525	3520	3535	-			4860		0780	0065	0080
B4	3445	3455	3455	-	.0130	3525	3520	3535	-			4280		0080	0065	0080
B5	3445	3450	3455	-	.0130	3525	3520	3535	-			4860		0080	0070	0080
B6	3450	3455	3455	-	.0125	3525	3520	3535	-			4940		0075	0065	0080
B7	3445	3450	3455	50	.0130	3525	3520	3535	20			4820		0080	0070	0080

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1B1S TEST PLATE NUMBER: XII

MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/8 inch

MAX DIA MANDREL: 0.3580 inch MANDREL MATERIAL: Carbonyl 883 (GE)

MANDREL TAPER: 0.015 inch/inch LUBRICATION: Fel Pro 300

TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 3/8 inch

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot			Top	Mid.	Bot.						Top	Mid.	Bot
C1	3395	3395	3395	-	.0185	3510	3505	3525	-			5260		0115	0110	0130
C2	3395	3395	3395	-	.0185	3515	3510	3520	-			5200		0120	0115	0125
C3	3395	3395	3395	80	.0185	3515	3510	3525	35			5500		0120	0115	0130
C4	3395	3395	3395	-	.0185	3515	3510	3525	-			5880		0120	0115	0130
C5	3395	3395	3395	-	.0185	3515	3510	3525	-			7360		0120	0115	0130

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1B2S TEST PLATE NUMBER: XII

MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/8 inch

MAX. DIA MANDREL: 0.3580 inch MANDREL MATERIAL: Carbolloy 883 (GE)

MANDREL TAPER: 0.030 inch/inch LUBRICATION: Fel Pro 300

TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 3/8 inch

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid	Bot			Top	Mid	Bot						Top	Mid	Bot
C6	3395	3395	3395	-	.0185	3515	3510	3525	-			7000		0120	0115	0130
C7	3395	3395	3395	80	.0185	3315	3510	3525	35			6420		0120	0115	0130
C8	3395	3395	3395	-	.0185	3515	3510	3525	-			6000		0120	0115	0130
D1	3395	3395	3395	-	.0185	3515	3510	3525	-			5780		0120	0115	0130
D2	3395	3395	3395	-	.0185	3515	3510	3525	-			7480		0120	0115	0130

\* To nearest 0.0005 inch

PHASE I. TASK I. MANDREL TAPER DETERMINATION

TEST NUMBER: 1B3S TEST PLATE NUMBER: XII

MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/8 inch

MAX. DIA. MANDREL: 0.3580 inch MANDREL MATERIAL: Carboly 883 (GE)

MANDREL TAPER: 0.045 inch/inch LUBRICATION: Fel Pro 300

TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 3/8 inch

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
D3	3395	3395	3395	-	.0185	3515	3510	3525	-			5980		0120	0115	0130
D4	3395	3395	3395	-	.0185	3515	3510	3525	-			6040		0120	0115	0130
D5	3395	3395	3395	80	.0185	3515	3510	3525	30			7660		0120	0115	0130
D6	3395	3395	3395	-	.0185	3515	3510	3525	-			6900		0120	0115	0130
D7	3395	3395	3395	-	.0185	3515	3510	3525	-			5880		0120	0115	0130

\* To nearest 0.0005 inch

## PHASE I--TASK I-MANDREL TAPER DETERMINATION

TEST NUMBER:	1C1S	TEST PLATE NUMBER:	XII
MANDREL:	Push (Design per BAC 5972)	NOMINAL SIZE:	3/8 inch
MAX. DIA. MANDREL:	0.3580 inch	MANDREL MATERIAL:	Carboloy 883 (GE)
MANDREL TAPER:	0.015 inch/inch	LUBRICATION:	Fel Pro 300
TEST MATERIAL:	300 'M' Steel (280/300 ksi)	STACK UP:	3/8 inch

[illegible]

\* To nearest 0.0005 inch

# PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1D1S TEST PLATE NUMBER: XIII

MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/8 inch

MAX. DIA. MANDREL: 0.3580 inch MANDREL MATERIAL: Carboloy 883 (GE)

MANDREL TAPER: 0.030 inch/inch LUBRICATION: Fel Pro 300

TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 3/8 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
A2	3440	3440	3445	-	.0140	3535	3510	3535				6080		0085	0070	0095
A3	3440	3440	3440	40	.0140	3525	3515	3535				5220		0075	0075	0095
B1**	3435	3534	3445	45	.0145	3505	3500	3515				5200	.0010	0070	0065	0070
B2**	3455	3440	3445	-	.0140	3510	3505	3520				4800	.0010	0055	0065	0075

\*To nearest 0.0005 inch

\*\*Sleeve used; maximum expansion does not include sleeve throat.

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1E1S TEST PLATE NUMBER: XIII

MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/8 inch

MAX. DIA. MANDREL: 0.3580 inch MANDREL MATERIAL: Carboly 883 (GE)

MANDREL TAPER: 0.030 inch/inch LUBRICATION: Fel Pro 300

TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 3/8 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
C1	3395	3390	3395	80	.0190	3515	3500	3535				6,640		0120	0110	0140
C2	3395	3380	3390	-	.0200	3515	3500	3535				6,680		0120	0120	0135
D1**	3395	3390	3395	90	.0190	3495	3485	3515				13,100	.0015	0010	0095	0120
D2**	3390	3385	3385	-	.0195	3495	3485	3515				9,200	.0015	0105	0100	0130

\*\*Sleeve used; maximum expansion does not include sleeve thinout.

\* To nearest 0.0005 inch



TEST NUMBER:	1F2S	TEST PLATE NUMBER:	XIII
MANDREL:	Push (Design per BAC 5972)	NOMINAL SIZE:	3/8 inch
MAX. DIA. MANDREL:	0.3580 inch	MANDREL MATERIAL:	Carboloy 883 (GE)
MANDREL TAPER:	0.030 inch/inch	LUBRICATION:	Fel Pro 300
TEST MATERIAL:	300 'M' Steel (280/300 ksi)	STACK UP:	1-3/8 inch

[illegible]

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TEST NUMBER:	1F3S	TEST PLATE NUMBER:	XIII
MANDREL:	Push (Design per BAC 5972)	NOMINAL SIZE:	3/8 inch
MAX. DIA. MANDREL:	0.3580 inch	MANDREL MATERIAL:	Carboloy 883 (GE)
MANDREL TAPER:	0.0045 inch/inch	LUBRICATION:	Fel Pro 300
TEST MATERIAL:	300 'M' Steel (280/300 ksi)	STACK UP:	1-3/8 inch

[illegible]

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TEST NUMBER:	1G2S	TEST PLATE NUMBER:	XIII
MANDREL:	Push (Design: per BAC 5972)	NOMINAL SIZE:	3/8 inch
MAX. DIA. MANDREL:	0.3580 inch	MANDREL MATERIAL:	Carboloy 883 (GE)
MANDREL TAPER:	0.030 inch/inch	LUBRICATION:	Fel Pro 300
TEST MATERIAL:	300 'M' Steel (280/300 ksi)	STACK UP:	1-3/8 inch

[illegible]

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TEST NUMBER:	1J15	TEST PLATE NUMBER:	XIV
MANDREL:	Push (Design per BAC 5972)	NOMINAL SIZE:	3/4 inch
MAX. DIA. MANDREL:	0.7280 inch	MANDREL MATERIAL:	Carboloy 883 (GE)
MANDREL TAPER:	0.015 inch/inch	LUBRICATION:	Fel Pro 300
TEST MATERIAL:	300 'M' Steel (280/300 ksi)	STACK UP:	2 inch

[illegible]

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TEST NUMBER:	1J2S	TEST PLATE NUMBER:	XIV
MANDREL:	Push (Design per BAC 5972)	NOMINAL SIZE:	3/4 inch
MAX. DIA. MANDREL:	0.7280 inch	MANDREL MATERIAL:	Carboloy 883 (GE)
MANDREL TAPER:	0.030 inch/inch	LUBRICATION:	Fel Pro 300
TEST MATERIAL:	300 'M' Steel (280/300 ksi)	STACK UP:	2 inch

\* To nearest 0.0005 inch

TEST NUMBER:	1J3S	TEST PLATE NUMBER:	XIV
MANDREL:	Push (Design per BAC 5972)	NOMINAL SIZE:	3/4 inch
MAX. DIA. MANDREL:	0.7280 inch	MANDREL MATERIAL:	Carboloy 883 (GE)
MANDREL TAPER:	0.045 inch/inch	LUBRICATION:	Fel Pro 300
TEST MATERIAL:	300 'M' Steel (280/300 ksi)	STACK UP:	2 inch

[illegible]

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## PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER:	1K1S	TEST PLATE NUMBER:	XVI
MANDREL:	Push (Design per BAC 5972)	NOMINAL SIZE:	3/4 inch
MAX. DIA. MANDREL:	0.7280 inch	MANDREL MATERIAL:	Carboloy 863 (GE)
MANDREL TAPER:	0.015 inch/inch	LUBRICATION:	Fel Pro 300
TEST MATERIAL:	300 'M' Steel (280/300 ksi)	STACK UP:	2 inch

[illegible]

\* To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1K2S TEST PLATE NUMBER: XVI  
 MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/4 inch  
 MAX. DIA. MANDREL: 0.7280 inch MANDREL MATERIAL: Carboloy 883 (GE)  
 MANDREL TAPER: 0.030 inch/inch LUBRICATION: Fel Pro 300  
 TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 2 inch

Hole no	Size prior to CW*			Finish prior to LW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid	Bot			Top	Mid	Bot						Top	Mid	Bot
B3	7030	7035	7030	60	.0245	7165	7155	7195	25			27,350		0135	0120	0165
B4	7030	7035	7035	-	.0245	7165	7155	7200	-			20,800		0135	0120	0165
C1	7035	7035	7030	-	.0245	7165	7160	7200	-			22,500		0130	0125	0170
C2	7035	7035	7045	-	.0245	7175	7160	7205	-			40,500		0140	0125	0160
C3	7030	7035	7035	-	.0245	7175	7165	7205	-			45,900		0145	0130	0170

\* To nearest 0.0005 inch



## PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER:	1L1S	TEST PLATE NUMBER:	XV
MANDREL:	Push (Design per BAC 5972)	NOMINAL SIZE:	3/4 inch
MAX. DIA. MANDREL:	0.7280 inch	MANDREL MATERIAL:	Carboloy 883 (GE)
MANDREL TAPER:	0.015 inch/inch	LUBRICATION:	Fel Pro 300
TEST MATERIAL:	300 'M' Steel (280/300 ksi)	STACK UP:	2 inch

[illegible]

TO ORDER: 9 0005 inch

TEST NUMBER:	2S	TEST PLATE NUMBER:	XV
MANDREL:	Push (Design per BAC 5972)	NOMINAL SIZE:	3/4 inch
MAX. DIA. MANDREL:	0.7280 inch	MANDREL MATERIAL:	Carboloy 883 (GE)
MANDREL TAPER:	0.030 inch/inch	LUBRICATION:	Fel Pro 300
TEST MATERIAL:	300 'M' Steel (280/300 ksi)	STACK UP:	2 inch

[illegible]

\* To nearest 0.0005 inch

TEST NUMBER:	1L3S	TEST PLATE NUMBER:	XV
MANDREL:	Push (Design per BAC 5972)	NOMINAL SIZE:	3/4 inch
MAX. DIA. MANDREL:	0.7280 inch	MANDREL MATERIAL:	Carboloy 883 (GE)
MANDREL TAPER:	0.045 inch/inch	LUBRICATION:	FelPro 300
TEST MATERIAL:	300 "M" Steel (280/300 ksi)	STACK UP:	2 inch

43150069 0 15005 17ch

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIA

NOMINAL EXPANSION VALUE: 0.025 in.

## GENERAL TEST CONDITIONS

DATE: 11/2/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 2024 T-851  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3540 in.  
 Lubrication: Fel Pro 300 (on sleeve)









### 2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

### 4. Fatigue Conditions

Net stress: 30 ksi max.  
 Test load: 8650 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6200/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

2024  
 0.025-in. interference  
 30 ksi

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II A1	1	.3500	.3635	.3735	10	6	—	.0240	.0135	200+	 .028 in. Bow (Counter didn't work) 
	2	.3500	.3635	.3735	15	12	—	.0240	.0135		
II A2	1	.3500	.3655	.3735	15	10	5	.0240	.0155	353	 .022 in. Bow 
	2	.3500	.3655	.3735	20	12	—	.0240	.0155		
II A3	1	.3500	.3635	.3735	20	14	—	.0240	.0135	451	 .024 in. Bow 
	2	.3500	.3635	.3735	12	7	—	.0240	.0135		

 Taken at Minimum (midpoint)

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# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIA

NOMINAL EXPANSION VALUE: 0.025 in.

## GENERAL TEST CONDITIONS

DATE: 11/2/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 2  
Width: 1.50 in.  
Hole spacing: 1.50 in.  
Edge margin: 0.75 in.  
Material: 2024 T-851  
Material gauge: 0.250 in.  
Surface Treatment: Shot peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.010 in.  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM-12 -0-N  
CW Mandrel Taper: 0.045 inch/inch  
CW Mandrel Major Dia.: 0.3530 in.  
Lubrication: Fel Pro 300 (on sleeve)



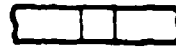

### 2. Hole Preparation

Nominal hole size: 3/8 in.  
Process: Drill, ream, CW & ream (1/64 in.)

2024  
0.025-in. interference  
30 ksi

### 4. Fatigue Conditions

Net stress: 30 ksi max  
Test load: 8650 lb  
Load ratio: (R) = 0.1  
Test Frequency: 6200/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
IIA 4	1	.3505	.3650	.3740	55	20	30	.0225	.0145	275	
	2	.3505	.3660	.3740	50	25	35	.0225	.0150		
											
											

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 118

NOMINAL EXPANSION VALUE: 0.020 in.

## GENERAL TEST CONDITIONS

DATE: 11/2/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 2024 T-851  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -O-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3540  
 Lubrication: Fel Pro 300 (on sleeve)









### 2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

2024  
 0.020 in. interference  
 30 ksi

### 4. Fatigue Conditions

Ner stress: 30 ksi max  
 Test load: 8650 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6200/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
B1	1	.3550	.3655	.3735	8	6	-	.0190	.0105	422	 .020 in. Bow  cw
	2	.3550	.3655	.3735	10	8	-	.0190	.0105		
B2	1	.3545	.3640	.3735	10	8	-	.0195	.0095	206	 .038 in. Bow  cw
	2	.3545	.3640	.3735	10	8	10	.0195	.0095		
B3	1	.3550	.3665	.3735	8	6	-	.0190	.0105	256	 16 in Bow  cw
	2	.3550	.3660	.3735	12	10		.0190	.0110		

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIB

NOMINAL EXPANSION VALUE: 0.020 in.

## GENERAL TEST CONDITIONS

DATE: 11/2/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 2024 T-851  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3539 in.  
 Lubrication: Fel Pro 300 (on sleeve)



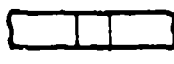

### 2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

2024  
 0.020-in. interference  
 30 ksi

### 4. Fatigue Conditions

Net stress: 30 ksi max  
 Test load: 8650 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6200/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11 B 4	1	.3550	.3660	.3740	45	18	30	.0189	.0110	310	
	2	.3550	.3645	.3735	50	20	35	.0189	.0095		
											
											

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIC

NOMINAL EXPANSION VALUE: 0.015 in.

## GENERAL TEST CONDITIONS

DATE: 11/2/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 2  
Width: 1.50 in.  
Hole spacing: 1.50 in.  
Edge margin: 0.75 in.  
Material: 2024 T-851  
Material gauge: 0.250 in.  
Surface Treatment: Shot peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.010 in.  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM - 12 -0-N  
CW Mandrel Taper: 0.045 inch/inch  
CW Mandrel Major Dia.: 0.3540 in.  
Lubrication: Fel Pro 300 (on sleeve)








### 2. Hole Preparation

Nominal hole size: 3/8 in.  
Process: Drill, ream, CW & ream (1/64 in.)

2024  
0.015-in. interference  
30 ksi

### 4. Fatigue Conditions

Net stress: 30 ksi max  
Test load: 8650 lb  
Load ratio: (R) = 0.1  
Test Frequency: 6200/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II C4	1	.3600	.3665	.3740	5	4	-	.0140	.0065	113	 .026 in. Bow  cw
	2	.3600	.3650	.3735	8	5	-	.0140	.0065		
II C2	1	.3600	.3665	.3735	10	8	10	.0140	.0065	148	 .010 in. Bow  cw
	2	.3600	.3650	.3740	10	8	-	.0140	.0050		
II C3	1	.3600	.3650	.3740	8	5	-	.0140	.0050	105	 .016 in. Bow  cw
	2	.3600	.3650	.3735	10	6	-	.0140	.0050		

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IID

NOMINAL EXPANSION VALUE: 0.010 in.

## GENERAL TEST CONDITIONS

DATE: 11/2/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 2024 T-851  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3540 in.  
 Lubrication: Fel Pro 300 (on sleeve)








### 2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

2024  
 0.010-in. interference  
 30 ksi

### 4. Fatigue Conditions

Net stress: 30 ksi max  
 Test load: 8600 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6200/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II D1	1	.3650	.3680	.3735	15	10	-	.0090	.0030	50	 .002 in. Bow  cw
	2	.3650	.3680	.3735	18	12	-	.0090	.0030		
II D2	1	.3650	.3670	.3735	24	15	10	.0090	.0020	68	 .004 in. Bow  cw
	2	.3650	.3680	.3735	20	14	-	.0090	.0030		
II D3	1	.3650	.3680	.3735	18	10	-	.0090	.0030	73	 .011 in. Bow  cw
	2	.3650	.3680	.3735	25	14	-	.0090	.0030		

 Taken at Minimum (midpoint)

# PHASE 1 - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11E

NOMINAL EXPANSION VALUE: 0.035 in.

## GENERAL TEST CONDITIONS

DATE: 11/2/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 2024 T-851  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.015 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM - 24 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.7164 in.  
 Lubrication: Fel Pro 300 (on sleeve)






### 2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

2024  
 0.035-in. interference  
 30 ksi

### 4. Fatigue Conditions

Net stress: 30 ksi max  
 Test load: 25,400 lb  
 Load ratio: (R) - 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrashore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11 E4	1	.7115	.7320	.7480	25	15	25	.0349	.0205	394	
	2	.7115	.7320	.7480	30	18	20	.0349	.0205		
11 E5	1	.7120	.7320	.7485	35	18	25	.0344	.0200	431	
	2	.7125	.7320	.7475	45	20	25	.0339	.0195		
											

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIE

NOMINAL EXPANSION VALUE: 0.035 in.

## GENERAL TEST CONDITIONS

DATE: 11/2/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 3  
Width: 3.00 in.  
Hole spacing: 3.00 in.  
Edge margin: 1.50 in.  
Material: 2024 T-851  
Material gauge: 0.375 in.  
Surface Treatment: Shot peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.015 in.  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM- 24 -0-N  
CW Mandrel Taper: 0.045 inch/inch  
CW Mandrel Major Dia.: 0.7164 in.  
Lubrication: Fel Pro 300 (on sleeve)







### 2. Hole Preparation

Nominal hole size: 3/4 in.  
Process: Drill, ream, CW & ream (1/64 in.)

### 4. Fatigue Conditions

Net stress: 40 ksi max  
Test load: 33,777 lb  
Load ratio: (R) = 0.1  
Test Frequency: 8000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibraphore (36 kip)

2024  
0.035 in. interference  
40 ksi

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II E-1	1	.7115	.7335	.7480	45	16	30	.0349	.0220	49	 .034 in. Bow  cw
	2	.7115	.7340	.7480	45	14	25	.0349	.0225		
											
											

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: II E

NOMINAL EXPANSION VALUE: 0.035 in.

## GENERAL TEST CONDITIONS

DATE: 11/2/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 2024 T-851  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.015 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 24 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.7164 in.  
 Lubrication: Fel Pro 300 (on sleeve)






### 2. Hole Preparation


Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

2024  
 0.035-in. interference  
 35 ksi

### 4. Fatigue Conditions

Net stress: 35 ksi max  
 Test load: 29,500 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 8000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II	1	.7115	.7340	.7480	35	16	35	.0349	.0225	112	 .029 in. Bow Grip failure
E2	2	.7115	.7340	.7480	35	12	32	.0349	.0225		
II	1	.7115	.7340	.7480	40	10	28	.0349	.0225	107	 .027 in. Bow cw
E3	2	.7115	.7335	.7480	45	12	30	.0349	.0220		
											

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIF

NOMINAL EXPANSION VALUE: 0.0315 ± 0.0015 in.

## GENERAL TEST CONDITIONS

DATE: 11/2/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 3  
Width: 3.00 in.  
Hole spacing: 3.00 in.  
Edge margin: 1.50 in.  
Material: 2024 T-851  
Material gauge: 0.375 in.  
Surface Treatment: Shot peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.015 in.  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM- 24 -0-N  
CW Mandrel Taper: 0.045 inch/inch  
CW Mandrel Major Dia.: 0.7164 in.  
Lubrication: Fel Pro 300 (on sleeve)








### 2. Hole Preparation


Nominal hole size: 3/4 in.  
Process: Drill, ream, CW & ream (1/64 in.)

### 4. Fatigue Conditions

Net stress: 30 ksi max  
Test load: 25,400 lb  
Load ratio: (R) = 0.1  
Test Frequency: 6500/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibraphore (36 kip)

2024  
0.032-in. interference  
30 ksi

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II F-1	1	.7140	.7340	.7480	44	20	30	.0324	.0200	392	 .012 in. Bow  cw
	2	.7140	.7340	.7480	50	25	35	.0324	.0200		
II F-2	1	.7165	.7345	.7480	40	20	12	.0304	.0180	285	 .009 in. Bow  cw
	2	.7140	.7340	.7480	45	20	15	.0324	.0200		
II F-3	1	.7150	.7345	.7480	45	20	25	.0314	.0195	360	 .022 in. Bow  cw
	2	.7140	.7340	.7480	45	25	30	.0324	.0200		

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIG

NOMINAL EXPANSION VALUE: 0.0265 ± 0.0055 in.

## GENERAL TEST CONDITIONS

DATE: 11/2/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 3  
Width: 3.00 in.  
Hole spacing: 3.00 in.  
Edge margin: 1.50 in.  
Material: 2024 T-851  
Material gauge: 0.375 in.  
Surface Treatment: Shot peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.015 in.  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM- 24 -0-N  
CW Mandrel Taper: 0.045 inch/inch  
CW Mandrel Major Dia.: .7164 in.  
Lubrication: Fel Pro 300 (on sleeve)







### 2. Hole Preparation

Nominal hole size: 3/4 in.  
Process: Drill, ream, CW & ream (1/64 in.)

2024  
0.027-in. interference  
30 ksi

### 4. Fatigue Conditions

Net stress: 30 ksi max  
Test load: 25,500 lb  
Load ratio: (R) = 0.1  
Test Frequency: 6500/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II G1	1	.7195	.7345	.7480	20	12	28	.0269	.0150	245	 Grip failure .020 in. Bow
	2	.7195	.7345	.7480	14	8	25	.0269	.0150		
II G2	1	.7195	.7345	.7480	10	8	75	.0269	.0150	297	 .020 in. Bow  cw
	2	.7195	.7350	.7480	23	10	70	.0269	.0155		
G3	1	.7195	.7350	.7480	26	12	20	.0269	.0155	297	 .010 in. Bow  cw
	2	.7195	.7345	.7480	16	10	25	.0269	.0150		

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11H

NOMINAL EXPANSION VALUE: 0.025 in.

## GENERAL TEST CONDITIONS

DATE: 11/2/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 2024 T-851  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.015 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 24 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.7164 in.  
 Lubrication: Fel Pro 300 (on sleeve)




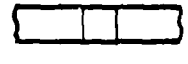

### 2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

2024  
 0.025-in. interference  
 35 ksi

### 4. Fatigue Conditions

Net stress: 35 ksi max  
 Test load: 29,800 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11H1	1	.7235	.7355	.7480	50	20	55	.0229	.0120	55	 .015 in. Bow  cw
	2	.7235	.7350	.7480	32	15	40	.0229	.0125		
											
											

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11H

NOMINAL EXPANSION VALUE: 0.025 in.

## GENERAL TEST CONDITIONS

DATE: 11/2/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 2024 T-851  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.015 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 24 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.7164 in.  
 Lubrication: Fel Pro 300 (on sleeve)





### 2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

2024  
 0.025-in. interference  
 30 ksi

### 4. Fatigue Conditions

Net stress: 30 ksi max  
 Test load: 25,400 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11H2	1	.7235	.7355	.7480	32	17	45	.0229	.0120	164	 .015 in. Bow cw
	2	.7235	.7355	.7480	50	25	42	.0229	.0120		
11H3	1	.7235	.7355	.7480	50	23	45	.0229	.0120	274	 .025 in. Bow cw
	2	.7235	.7355	.7480	40	16	30	.0229	.0120		
11H4	1	.7230	.7340	.7480	35	15	20	.0234	.0110	181	
	2	.7230	.7340	.7480	30	12	25	.0234	.0110		

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11J

NOMINAL EXPANSION VALUE: 0.025 in.

## GENERAL TEST CONDITIONS

DATE: 11/10/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3530 in.  
 Lubrication: Fel Pro 300 (on sleeve)





### 2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
 0.025-in. interference  
 60 and 70 ksi

### 4. Fatigue Conditions

Net stress: See remarks  
 Test load: 20,200 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11J1	1	.3500	.3625	.3735	70	30	25	.0220	.0125	2,187 591	 60 ksi (1st run) 70 ksi (cont'd run) ↑ CW
	2	.3500	.3625	.3735	60	25	20	.0220	.0125		
											
											

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIJ

NOMINAL EXPANSION VALUE: 0.026 in.

## GENERAL TEST CONDITIONS

DATE: 11/10/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.0250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3530 in.  
 Lubrication: Fel Pro 300 (on sleeve)



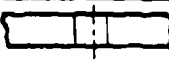


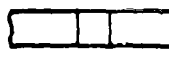
### 2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
 0.025-in. interference  
 70 ksi

### 4. Fatigue Conditions

Net stress: 70 ksi max  
 Test load: 20,200 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II	1	.3505	.3625	.3735	60	35	25	.0215	.0120	932	
J2	2	.3505	.3625	.3735	70	30	20	.0215	.0120		
II	1	.3495	.3645	.3730	20	10	15	.0225	.0150	181	 Different mandrel used—dia = .3540 in.  cw
J4	2	.3495	.3645	.3730	—	—	—	.0225	.0150		
											

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIIJ

NOMINAL EXPANSION VALUE: 0.025 in.

## GENERAL TEST CONDITIONS

DATE: 11/10/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3530 in.  
 Lubrication: Fel Pro 300 (on sleeve)





### 2. Hole Preparation


Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
 0.025-in. interference  
 80 ksi

### 4. Fatigue Conditions

Net stress: 80 ksi max  
 Test load: 23,100 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II	1	.3505	.3625	.3735	60	30	20	.0215	.0120	77	 ↑ CW
J3	2	.3505	.3625	.3735	55	25	25	.0215	.0120		
											
											

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11J

NOMINAL EXPANSION VALUE: 0.025 in.

## GENERAL TEST CONDITIONS

DATE: 11/10/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 2  
Width: 1.50 in.  
Hole spacing: 1.50 in.  
Edge margin: 0.75 in.  
Material: 6Al-4V Ti  
Material gauge: 0.250 in.  
Surface Treatment: Shot peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.010 in.  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-C8M- 12 -0-N  
CW Mandrel Taper: 0.045 inch/inch  
CW Mandrel Major Dia.: 0.3540 in.  
Lubrication: Fel Pro 300 (on sleeve)



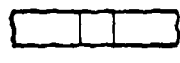
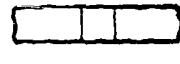
### 2. Hole Preparation

Nominal hole size: 3/8 in.  
Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
0.025-in. interference  
75 ksi

### 4. Fatigue Conditions

Net stress: 75 ksi max  
Test load: 20,100 lb  
Load ratio: (R) 0.1  
Test Frequency: 6500/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11 J5	1	.3495	.3645	.3730	15	10	15	.0225	.0150	110	 CW
	2	.3495	.3645	.3730	-	-	-	.0225	.0150		
											
											

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11K

NOMINAL EXPANSION VALUE: 0.016 in.

## GENERAL TEST CONDITIONS

DATE: 11/10/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3540 in.  
 Lubrication: Fel Pro 300 (on sleeve)





### 2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
 0.016-in. interference  
 70 ksi

### 4. Fatigue Conditions

Net stress: 70 ksi max  
 Test load: 20,200 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophone

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11K4	1	.3560	.3655	.3730	15	10	15	.0170	.0096	196	 CW
	2	.3560	.3660	.3730	-	-	-	.0170	.0100		
11K5	1	.3560	.3655	.3730	15	10	15	.0170	.0096	94	 CW
	2	.3560	.3655	.3730	-	-	-	.0170	.0096		
											

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIK

NOMINAL EXPANSION VALUE: 0.020 in.

## GENERAL TEST CONDITIONS

DATE: 11/10/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 2  
Width: 1.50 in.  
Hole spacing: 1.50 in.  
Edge margin: 0.75 in.  
Material: 6Al-4V Ti  
Material gauge: 0.250 in.  
Surface Treatment: Shot peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.010 in.  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM- 12 -G-N  
CW Mandrel Taper: 0.045 inch/inch  
CW Mandrel Major Dia.: 0.3530 in.  
Lubrication: Fel Pro 300 (on sleeve)




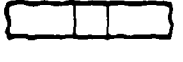

### 2. Hole Preparation

Nominal hole size: 3/8 in.  
Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
0.020-in. interference  
80 ksi

### 4. Fatigue Conditions

Net stress: 80 ksi max  
Test load: 23,000 lb  
Load ratio: (R) 0.1  
Test Frequency: 6500/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II	1	.3560	.3635	.3730	60	30	20	.0160	.0075	58	 CW
K1	2	.3560	.3635	.3730	70	35	16	.0160	.0075		
											
											

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11K

NOMINAL EXPANSION VALUE: 0.020 in.

## GENERAL TEST CONDITIONS

DATE: 11/10/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 2  
Width: 1.50 in.  
Hole spacing: 1.50 in.  
Edge margin: 0.75 in.  
Material: 6Al-4V Ti  
Material gauge: 0.250 in.  
Surface Treatment: Shot peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.010 in.  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM-12 -0-N  
CW Mandrel Taper: 0.045 inch/inch  
CW Mandrel Major Dia.: 0.3530 in.  
Lubrication: Fel Pro 300 (on sleeve)





### 2. Hole Preparation

Nominal hole size: 3/8 in.  
Process: Drill, ream, CW & ream (1/54 in.)

6Al-4V  
0.020 in. interference  
75 ksi

### 4. Fatigue Conditions

Net stress: 75 ksi max  
Test load: 21,800 lb  
Load ratio: (R) = 0.1  
Test Frequency: 6500/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After C/V	After Ream				
11 K2		.3555	.3635	.3730	80	45	20	.0185	.0080	113	 CW
		.3365	.3635	.3730	75	35	15	.0160	.0075		
											
											

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIK

NOMINAL EXPANSION VALUE: 0.020 in.

## GENERAL TEST CONDITIONS

DATE: 11/10/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3530 in.  
 Lubrication: Fel Pro 300 (on sleeve)






### 2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
 0.020 in. interference  
 70 ksi

### 4. Fatigue Conditions

Net stress: 70 ksi max  
 Test load: 20,200 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II	1	.3565	.3635	.3730	60	30	15	.0155	.0070	224	 ↑ CW
K3	2	.3555	.3635	.3730	75	40	20	.0165	.0080		
II	1	.3560	.3655	.3730	15	10	15	.0170	.0095	196	 ↑ CW Different mandrel used—dia = .3540 in.
K4	2	.3560	.3655	.3730	-	-	-	.0170	.0100		
											

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: III

NOMINAL EXPANSION VALUE: 0.015 in.

## GENERAL TEST CONDITIONS

DATE: 11/10/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 2  
Width: 1.50 in.  
Hole spacing: 1.50 in.  
Edge margin: 0.75 in.  
Material: 6Al-4V Ti  
Material gauge: 0.250 in.  
Surface Treatment: Shot peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.010 in.  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM- 12 -0-N  
CW Mandrel Taper: 0.045 inch/inch  
CW Mandrel Major Dia.: 0.3530 in.  
Lubrication: Fel Pro 300 (on sleeve)





### 2. Hole Preparation

Nominal hole size: 3/8 in.  
Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
0.015-in. interference  
70 ksi

### 4. Fatigue Conditions

Net stress: 70 ksi max  
Test load: 20,200 lb  
Load ratio: (R) = 0.1  
Test Frequency: 6500/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (KHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II L1	1	.3615	.3650	.3730	80	45	15	.0105	.0035	102	 ↑ CW
	2	.3615	.3650	.3730	70	45	20	.0105	.0035		
II L2	1	.3615	.3650	.3730	80	50	10	.0105	.0035	140	 ↑ CW
	2	.3610	.3650	.3730	60	40	15	.0110	.0040		
II L3	1	.3610	.3650	.3730	50	35	20	.0110	.0040	95	 ↑ CW
	2	.3615	.3650	.3730	60	40	15	.0105	.0035		

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIM

NOMINAL EXPANSION VALUE: 0.010 in.

## GENERAL TEST CONDITIONS

DATE: 11/10/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 6Al-4V T<sub>i</sub>  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-C8M- 12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3530  
 Lubrication: Fel Pro 300 (on sleeve)





### 2. Hole Preparation


Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
 0.010-in. interference  
 70 ksi

### 4. Fatigue Conditions

Net stress: 70 ksi max  
 Test load: 20,100 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II M1	1	.3665	.3675	.3735	70	40	20	.0065	.0010	53	 ↑ CW
	2	.3660	.3675	.3735	60	20	25	.0060	.0015		
II M2	1	.3660	.3675	.3735	60	35	18	.0060	.0015	57	 ↑ CW
	2	.3660	.3675	.3735	70	40	25	.0060	.0015		
II M3	1	.3660	.3675	.3735	70	35	15	.0060	.0015	48	 ↑ CW
	2	.3660	.3675	.3735	75	45	20	.0060	.0015		

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIN

NOMINAL EXPANSION VALUE: 0.035 in

## GENERAL TEST CONDITIONS

DATE: 11/10/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.015 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 24 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.7140  
 Lubrication: Fel Pro 300 (on sleeve)





### 2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
 0.035-in. interference  
 70 ksi

### 4. Fatigue Conditions

Net stress: 70 ksi max  
 Test load: 60,300 lb  
 Load ratio: (R) : 0.1  
 Test Frequency: 4500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (100 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II N1	1	.7095	.7290	.7485	100	45	20	.0325	.0195	105	 ↑ CW
	2	.7095	.7290	.7485	-	-	-	.0325	.0195		
II N2	1	.7095	.7290	.7485	-	-	-	.0325	.0195	65	 ↑ CW
	2	.7095	.7290	.7485	-	-	-	.0325	.0195		
II N3	1	.7095	.7290	.7485	100	50	20	.0325	.0195	30	 Discolored ↑ CW
	2	.7095	.7290	.7485	-	-	-	.0325	.0195		

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 110

NOMINAL EXPANSION VALUE: 0.030 in.

## GENERAL TEST CONDITIONS

DATE: 11/10/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 3  
Width: 3.00 in.  
Hole spacing: 3.00 in.  
Edge margin: 1.50 in.  
Material: 6Al-4V Ti  
Material gauge: 0.375 in.  
Surface Treatment: Shot peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.015 in.  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM- 24 -0-N  
CW Mandrel Taper: 0.045 inch/inch  
CW Mandrel Major Dia.: 0.7140  
Lubrication: Fel Pro 300 (on sleeve)






### 2. Hole Preparation

Nominal hole size: 3/4 in.  
Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
0.030-in. interference  
70 ksi

### 4. Fatigue Conditions

Net stress: 70 ksi max  
Test load: 60,200 lb  
Load ratio: (R) = 0.1  
Test Frequency: 4500/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibraphore (100 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11 O1	1	.7130	.7295	.7485	80	35	10	.0290	.0165	95	 ↓ CW
	2	.7145	.7295	.7485	-	-	-	.0275	.0150		
11 O2	1	.7130	.7295	.7485	-	-	-	.0290	.0165	78	 ↑ CW
	2	.7140	.7295	.7485	-	-	-	.0280	.0155		
11 O3	1	.7130	.7295	.7485	90	45	15	.0290	.0165	60	 ↑ CW
	2	.7140	.7295	.7485	-	-	-	.0280	.0155		

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 110

NOMINAL EXPANSION VALUE: 0.030 in.

## GENERAL TEST CONDITIONS

DATE: 11/10/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 3  
Width: 3.00 in.  
Hole spacing: 3.00 in.  
Edge margin: 1.50 in.  
Material: 6Al-4V Ti  
Material gauge: 0.375 in.  
Surface Treatment: Shot peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.015 in.  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM- 24 -0-N  
CW Mandrel Taper: 0.045 inch/inch  
CW Mandrel Major Dia.: 0.7140  
Lubrication: Fel Pro 300 (on sleeve)





### 2. Hole Preparation


Nominal hole size: 3/4 in.  
Process: Drill, ream, CW (not postreamed)

6Al-4V  
0.030-in. interference  
70 ksi

### 4. Fatigue Conditions

Net stress: 70 ksi max  
Test load: 60,100 lb  
Load ratio: (R) = 0.1  
Test Frequency: 4500/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibraphore (100 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11	1	.7140	.7290	-	20	15	-	.0290	.0150	95	 ↑ CW
	2	.7140	.7290	-	25	20	-	.0290	.0150		
11	1	.7140	.7290	-	25	20	-	.0290	.0150	95	 ↑ CW
	2	.7140	.7290	-	25	20	-	.0290	.0150		
											

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIP

NOMINAL EXPANSION VALUE: 0.025 in.

## GENERAL TEST CONDITIONS

DATE: 11/10/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 3  
Width: 3.00 in.  
Hole spacing: 3.00 in.  
Edge margin: 1.50 in.  
Material: 6Al-4V Ti  
Material gauge: 0.375 in.  
Surface Treatment: Shot peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.015 in. (thin out .001 in.)  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM- 24 -G-N  
CW Mandrel Taper: 0.045 inch/inch  
CW Mandrel Major Dia.: 0.7140 in.  
Lubrication: Fel Pro 300 (on sleeve)






### 2. Hole Preparation

Nominal hole size: 3/4 in.  
Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
0.025-in. interference  
70 ksi

### 4. Fatigue Conditions

Net stress: 70 ksi max  
Test load: 60,300 lb  
Load ratio: (R) 0.1  
Test Frequency: 4500/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibraphore (100 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
IIP 1	1	.7190	.7305	.7485	80	35	20	.0230	.0115	52	 ↓ CW
	2	.7185	.7305	.7485	-	-	-	.0235	.0120		
IIP 2	1	.7185	.7305	.7485	-	-	-	.0235	.0120	71	 ↑ CW
	2	.7190	.7305	.7485	-	-	-	.0230	.0115		
IIP 3	1	.7190	.7305	.7485	80	35	20	.0230	.0115	53	 ↑ CW
	2	.7185	.7305	.7485	-	-	-	.0235	.0120		

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11Q

NOMINAL EXPANSION VALUE: 0.020 in.

## GENERAL TEST CONDITIONS

DATE: 11/10/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 3  
Width: 3.00 in.  
Hole spacing: 3.00 in.  
Edge margin: 1.50 in.  
Material: 6Al-4V Ti  
Material gauge: 0.375 in.  
Surface Treatment: Shot peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.015 in.  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM- 24 -0-N  
CW Mandrel Taper: 0.045 inch/inch  
CW Mandrel Major Dia.: 0.7140 in.  
Lubrication: Fel Pro 300 (on sleeve)






### 2. Hole Preparation

Nominal hole size: 3/4 in.  
Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
0.020-in. interference  
70 ksi

### 4. Fatigue Conditions

Net stress: 70 ksi max  
Test load: 60,100 lb  
Load ratio: (R) = 0.1  
Test Frequency: 4500/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibraphore (100 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11Q1	1	.7235	.7315	.7485	8	5	15	.0185	.0080	25	 ↓ CW
	2	.7240	.7315	.7485	-	-	-	.0180	.0075		
11Q2	1	.7235	.7315	.7485	-	-	-	.0185	.0080	47	 ↑ CW
	2	.7240	.7315	.7485	-	-	-	.0180	.0075		
11Q3	1	.7235	.7315	.7485	8	5	20	.0185	.0080	44	 ↑ CW
	2	.7240	.7315	.7485	-	-	-	.0180	.0075		

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIR

NOMINAL EXPANSION VALUE: NONE

## GENERAL TEST CONDITIONS

DATE: 11/17/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

### 3. CW Process (not used)

Sleeve type: \_\_\_\_\_  
 Sleeve thickness: \_\_\_\_\_  
 Sleeve orientation: \_\_\_\_\_  
 CW Mandrel: \_\_\_\_\_  
 CW Mandrel Taper: \_\_\_\_\_  
 CW Mandrel Major Dia.: \_\_\_\_\_  
 Lubrication: \_\_\_\_\_




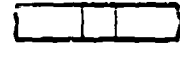
### 2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill and ream only

6Al-4V  
 Reamed only  
 70 ksi

### 4. Fatigue Conditions

Net stress: 70 ksi max  
 Test load: 59,300 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 4500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (100 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
R 1	1	-	-	.7510	-	-	25	-	-	38	 cv.
	2	-	-	.7500	-	-	20	-	-		
R 2	1	-	-	.7500	-	-	25	-	-	28	
	2	-	-	.7500	-	-	25	-	-		
											

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIS

NOMINAL EXPANSION VALUE: 0.025 in.

## GENERAL TEST CONDITIONS

DATE: 12/7/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 300 M steel  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

### 3. CW Process

Sleeve type: None used  
 Sleeve thickness: -  
 Sleeve orientation: -  
 CW Mandrel: Push (design per BAC 5972)  
 CW Mandrel Taper: 0.030 in./in.  
 CW Mandrel Major Dia.: 0.3580  
 Lubrication: Fel Pro 300

### 2. Hole Preparation





Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

300M  
 0.025 in. interference  
 110 ksi

Edges cupped on fracture surface from effect of shot peen; hole edges similar

### 4. Fatigue Conditions

Net stress: 110 ksi max  
 Test load: 31,400 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 7000/min  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II S1	1	0.3335	0.3505	0.3725	90	75	20	0.0245	0.0170	253	 cw
	2	0.3335	0.3505	0.3725	-	-	-	0.0245	0.0170		
II S2	1	0.3330	0.3505	0.3725	85	70	25	0.0250	0.0170	249	 cw
	2	0.3335	0.3505	0.3725	-	-	-	0.0245	0.0170		
II S3	1	0.3335	0.3505	0.3730	90	75	60	0.0245	0.0170	135	 cw Hole not cleaned up
	2	0.3335	0.3510	0.3725	-	-	-	0.0245	0.0175		

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: II SA

NOMINAL EXPANSION VALUE: 0.021 in.

## GENERAL TEST CONDITIONS

DATE: 11/27/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 2  
Width: 1.50 in.  
Hole spacing: 1.50 in.  
Edge margin: 0.75 in.  
Material: 300 M steel  
Material gauge: 0.250  
Surface Treatment: Shot peen  
Fastener: None

### 3. CW Process

Sleeve type: None used  
Sleeve thickness: -  
Sleeve orientation: -  
CW Mandrel: Push (design per BAC 5972)  
CW Mandrel Taper: 0.045 in./in.  
CW Mandrel Major Dia.: 0.3580  
Lubrication: Fel Pro 300





### 2. Hole Preparation

Nominal hole size: 3/8 in.  
Process: Drill, ream, CW & ream (1/64 in.)

300M  
0.021 in. interference  
110 ksi

### 4. Fatigue Conditions

Net stress: 110 ksi max  
Test load: 31,300 lb  
Load ratio: (R) = 0.1  
Test Frequency: 4000/min  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibraphore (100 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II S4A	1	0.3370	0.3510	0.3720	35	17	20	0.0210	0.0140	55	 c/w
	2	0.3370	0.3510	0.3725	-	-	-	0.0210	0.0140		
II S5A	1	0.3370	0.3515	0.3720	30	15	20	0.0210	0.0145	44	 c/w
	2	0.3370	0.3515	0.3720	-	-	-	0.0210	0.145		
											

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: II SB

NOMINAL EXPANSION VALUE: 0.023 in.

## GENERAL TEST CONDITIONS

DATE: 11/27/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 2  
Width: 1.50 in.  
Hole spacing: 1.50 in.  
Edge margin: 0.75 in.  
Material: 300 M steel  
Material gauge: 0.250 in.  
Surface Treatment: Shot peen  
Fastener: None

### 3. CW Process

Sleeve type: None used  
Sleeve thickness:                       
Sleeve orientation:                       
CW Mandrel: Push (design per BAC 5972)  
CW Mandrel Taper: 0.045 in./in.  
CW Mandrel Major Dia.: 0.3580  
Lubrication: Fel Pro 300





### 2. Hole Preparation

Nominal hole size: 3/8 in.  
Process: Drill, ream, CW & ream (1/64 in.)

300M  
0.023 in. interference  
110 ksi

### 4. Fatigue Conditions

Net stress: 110 ksi max  
Test load: 31,300 lb  
Load ratio: (R) = 0.1  
Test Frequency: 4000/min  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II S6A	1	0.3350	0.3510	0.3720	30	15	20	0.0230	0.0160	Malfunction	 ↑ CW
	2	0.3350	0.3500	0.3720	-	-	-	0.0230	0.0150		
II S7A	1	0.3350	0.3500	0.3720	35	18	20	0.0230	0.0150	144	 ↑ CW
	2	0.3350	0.3505	0.3720	-	-	-	0.0230	0.0155		
											

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11T

NOMINAL EXPANSION VALUE: 0.020

## GENERAL TEST CONDITIONS

DATE: 12/7/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig 2  
Width: 1.50 in  
Hole spacing: 1.50 in.  
Edge margin: 0.75 in.  
Material: 300 M steel  
Material gauge: 0.250 in.  
Surface Treatment: Shot peen  
Fastener: None

### 3. CW Process

Sleeve type: None used  
Sleeve thickness: -  
Sleeve orientation: -  
CW Mandrel: Push (design per BAC 5972)  
CW Mandrel Taper: 0.030 in./in.  
CW Mandrel Major Dia.: 0.3580  
Lubrication: Fel Pro 300

### 2. Hole Preparation





Nominal hole size: 3/8 in.  
Process: Drill, ream, CW & ream (1/64 in.)


300M  
0.020 in. interference  
110 ksi

Failure edges corniced from shot peen effect

### 4. Fatigue Conditions

Net stress: 110 ksi max  
Test load: 31,400 lb  
Load ratio: (R) = 0.1  
Test Frequency: 6000/4000/min  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibraphure (36 & 100 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11	1	0.3390	0.3505	0.3725	60	50	15	0.0190	0.0115	77	 100 kip machine
11	2	0.3390	0.3505	0.3725	-	-	-	0.0190	0.0115		
12	1	0.3390	0.3510	0.3725	60	50	20	0.0190	0.0120	75	 36 kip machine
12	2	0.3390	0.3510	0.3725	-	-	-	0.0190	0.0120		
13	1	0.3390	0.3510	0.3725	60	45	15	0.0190	0.0120	70	 36 kip machine
13	2	0.3390	0.3510	0.3725	-	-	-	0.0190	0.0120		

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11 U

NOMINAL EXPANSION VALUE: 0.015 in.

## GENERAL TEST CONDITIONS

DATE: 12/7/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 2  
Width: 1.50 in.  
Hole spacing: 1.50 in.  
Edge margin: 0.75 in.  
Material: 300 M steel  
Material gauge: 0.250 in.  
Surface Treatment: Shot peen  
Fastener: None

### 3. CW Process

Sleeve type: None used  
Sleeve thickness: -  
Sleeve orientation: -  
CW Mandrel: Push (design per BAC 5972)  
CW Mandrel Taper: 0.030 in./in.  
CW Mandrel Major Dia.: 0.3580  
Lubrication: Fel Pro 300

### 2. Hole Preparation



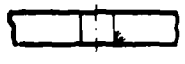


Nominal hole size: 3/8 in.  
Process: Drill, ream, CW & ream (1/64 in.)


300M  
0.015 in. interference  
110 ksi

Failure edges corniced from shot peen effect

### 4. Fatigue Conditions

Net stress: 110 ksi max  
Test load: 31,400 lb  
Load ratio: (R) = 0.1  
Test Frequency: 7000/4000/min  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibraphore (36 & 100 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II U1	1	0.3435	0.3515	0.3730	85	70	25	0.0145	0.0080	100	 36 kip machine c/w
	2	0.3435	0.3515	0.3730	-	-	-	0.0145	0.0080		
II U2	1	0.3435	0.3515	0.3725	85	70	20	0.0145	0.0080	52	 36 kip machine c/w
	2	0.3435	0.3515	0.3725	-	-	-	0.0145	0.0080		
II U3	1	0.3435	0.3515	0.3730	90	75	15	0.0145	0.0080	55	 36 & 100 kip machine c/w
	2	0.3430	0.3515	0.3730	-	-	-	0.0150	0.0085		

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIV

NOMINAL EXPANSION VALUE: 0.010 in.

## GENERAL TEST CONDITIONS

DATE: 12/7/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 300 M steel  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

### 3. CW Process

Sleeve type: None used  
 Sleeve thickness: -  
 Sleeve orientation: -  
 CW Mandrel: Push (design per BAC 5972)  
 CW Mandrel Taper: 0.030 in./in.  
 CW Mandrel Major Dia.: 0.3580  
 Lubrication: Fel Pro 300

### 2. Hole Preparation



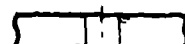
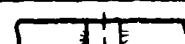
Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

300M  
 0.010 in. interference  
 110 ksi

Failure edges corniced from shot peen

### 4. Fatigue Conditions

Net stress: 110 ksi max  
 Test load: 31,400 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6500/min  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II V1	1	0.3480	0.3525	0.3725	35	30	20	0.0100	0.0045	37	 C/W
	2	0.3480	0.3525	0.3725	-	-	-	0.0100	0.0045		
II V2	1	0.3495	0.3525	0.3725	30	25	25	0.0085	0.0030	33	 C/W Hole edge corniced one side
	2	0.3495	0.3525	0.3725	-	-	-	0.0085	0.0030		
II V3	1	0.3490	0.3530	0.3725	30	25	40	0.0090	0.0040	33	 C/W
	2	0.3495	0.3525	0.3725	-	-	-	0.0085	0.0030		

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: II W

NOMINAL EXPANSION VALUE: 0.035 in.

## GENERAL TEST CONDITIONS

DATE: 12/7/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 300 M steel  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

### 3. CW Process

Sleeve type: None used  
 Sleeve thickness: -  
 Sleeve orientation: -  
 CW Mandrel: Push (design per BAC 5972)  
 CW Mandrel Taper: 0.030 in./in.  
 CW Mandrel Major Dia.: 0.7280  
 Lubrication: Fel Pro 300





### 2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

### 4. Fatigue Conditions

Net stress: 110 ksi max  
 Test load: 93,600 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/min  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (100 kip)

300M  
 0.035-in. interference  
 110 ksi

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II W1	1	0.6920	0.7140	0.7495	35	30	10	0.0360	0.0220	53	 c/w
	2	0.6925	0.7140	0.7495	-	-	-	0.0355	0.0215		
II W2	1	0.6920	0.7140	0.7495	30	25	15	0.0360	0.0220	80	 c/w
	2	0.6925	0.7140	0.7495	-	-	-	0.0355	0.0215		
II W3	1	0.6920	0.7140	0.7495	40	35	10	0.0360	0.0220	59	 c/w
	2	0.6925	0.7140	0.7495	-	-	-	0.0355	0.0215		

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11 X

NOMINAL EXPANSION VALUE: 0.030 in.

## GENERAL TEST CONDITIONS

DATE: 12/7/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 3  
Width: 3.00 in.  
Hole spacing: 3.00 in.  
Edge margin: 1.50 in.  
Material: 300 M steel  
Material gauge: 0.375 in.  
Surface Treatment: Shot peen  
Fastener: None

### 3. CW Process

Sleeve type: None used  
Sleeve thickness: -  
Sleeve orientation: -  
CW Mandrel: Push (design per BAC 5972)  
CW Mandrel Taper: 0.030 in./in.  
CW Mandrel Major Dia.: 0.7280  
Lubrication: Fel Pro 300





### 2. Hole Preparation

Nominal hole size: 3/4 in.  
Process: Drill, ream, CW & ream (1/64 in.)

### 4. Fatigue Conditions

Net stress: 110 ksi  
Test load: 93,500 lb  
Load ratio: (R) = 0.1  
Test Frequency: 5000/min  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibraphore (100 kip)

300M  
0.030 in. interference  
110 ksi

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11 X1	1	0.6955	0.7165	0.7495	40	35	10	0.0295	0.0180	41	 CW
	2	0.6985	0.7165	0.7495	-	-	-	0.0295	0.0180		
11 X2	1	0.6985	0.7165	0.7495	40	35	15	0.0295	0.0180	43	 CW
	2	0.6980	0.7165	0.7495	-	-	-	0.0300	0.0185		
11 X3	1	0.6985	0.7165	0.7495	35	30	15	0.0295	0.0180	48	 CW
	2	0.6980	0.7165	0.7495	-	-	-	0.0300	0.0185		

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: II Y

NOMINAL EXPANSION VALUE: 0.025 in.

## GENERAL TEST CONDITIONS

DATE: 12/7/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 3  
Width: 3.00 in.  
Hole spacing: 3.00 in.  
Edge margin: 1.50 in.  
Material: 300 M steel  
Material gauge: 0.375 in.  
Surface Treatment: Shot peen  
Fastener: None

### 3. CW Process

Sleeve type: None used  
Sleeve thickness: -  
Sleeve orientation: -  
CW Mandrel: Push (design per BAC 5972)  
CW Mandrel Taper: 0.030 in./in.  
CW Mandrel Major Dia.: 0.7280  
Lubrication: Fel Pro 300






### 2. Hole Preparation

Nominal hole size: 3/4 in.  
Process: Drill, ream, CW & ream (1/64 in.)

### 4. Fatigue Conditions

Net stress: 110 ksi max  
Test load: 93,400 lb  
Load ratio: (R) = 0.1  
Test Frequency: 5000/min  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibraphore (100 kip)

300M  
0.025-in. interference  
110 ksi

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II Y1	1	0.7025	0.7170	0.7495	50	45	10	0.0255	0.0135	36	 c/w
	2	0.7040	0.7165	0.7495	-	-	-	0.0240	0.0125		
II Y2	1	0.7020	0.7165	0.7495	45	40	15	0.0260	0.0145	39	 c/w
	2	0.7040	0.7170	0.7495	-	-	-	0.0240	0.0130		
II Y3	1	0.7035	0.7170	0.7495	45	40	10	0.0245	0.0135	31	 c/w
	2	0.7025	0.7170	0.7495	-	-	-	0.0255	0.0145		

 Taken at Minimum (midpoint)

# PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 112

NOMINAL EXPANSION VALUE: 0.0

## GENERAL TEST CONDITIONS

DATE: 12/7/72

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 3  
Width: 3.00 in.  
Hole spacing: 3.00 in.  
Edge margin: 1.50 in.  
Material: 300 M steel  
Material gauge: 0.375 in.  
Surface Treatment: Shot peen  
Fastener: None

### 3. CW Process

Sleeve type: None used  
Sleeve thickness: -  
Sleeve orientation: -  
CW Mandrel: Push (design per BAC 5972)  
CW Mandrel Taper: 0.030 in./in.  
CW Mandrel Major Dia.: 0.7280  
Lubrication: Fel Pro 300






### 2. Hole Preparation

Nominal hole size: 3/4 in.  
Process: Drill, ream, CW & ream (1/64 in.)

300M  
0.020 in. interference  
110 ksi

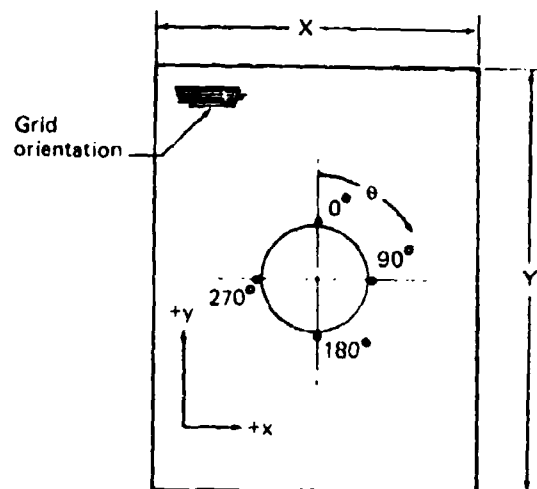
### 4. Fatigue Conditions

Net stress: 110 ksi max  
Test load: 93,500 lb  
Load ratio: (R) : 0.1  
Test Frequency: 5000/min  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibraphore (100 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11 Z1	1	0.7080	0.7175	0.7495	40	35	10	0.0200	0.0095	32	 c/w
	2	0.7080	0.7175	0.7495	-	-	-	0.0200	0.0095		
11 Z2	1	0.7080	0.7180	0.7495	40	35	10	0.0200	0.0100	64	 c/w
	2	0.7080	0.7180	0.7495	-	-	-	0.0200	0.0100		
11 Z3	1	0.7080	0.7175	0.7495	35	30	10	0.0200	0.0095	44	 c/w
	2	0.7080	0.7175	0.7495	-	-	-	0.0200	0.0095		

 Taken at Minimum (midpoint)

# PHASE I-TASK 2-MOIRE DATA



Specimen Configuration

View looking at exit side  
Same reference maintained both sides, i.e., 90° on entrance side  
is opposite 90° on exit side  
All strains are  $E_y$  component

- Area where strain was measured

Specimen no.	Material	Hole size	X (in.)	Y (in.)	<sup>a</sup> $\theta$ (deg)	Affected zone (in.)			
						(Exit face)		(Entrance face)	
						-Y	+Y	-Y	+Y
1	Al	Large	2.3	4.3	18	0.55	0.55	0.60	0.55
2	Al	↑	2.3	4.3	232	0.80	0.50	0.80	0.50
3	Ti	↓	2.8	3.0	38	0.65	0.65	0.65	0.65
4	Ti	↓	2.8	3.0	35	0.90	0.90	0.90	0.90
5	Al	Small	1.5	4.3	160	0.45	0.35	0.45	0.30
6	Al	↑	1.5	4.3	265	0.45	0.35	(b)	
7	Ti	↑	1.5	1.9	45	0.45	0.40	0.40	0.40
8	Ti	↑	1.5	1.9	50	0.40	0.35	0.35	0.35
9	Stl	↓	1.5	1.7	Not visible	0.40	0.35	0.35	0.30

Specimen no.	$E_y$ (exit face)				$E_y$ (entrance face)			
	0°	90°	180°	270°	0°	90°	180°	270°
1	.094	.018	.020	.016	.063	.010	.029	.010
2	.025	.018	.110	.028	.030	.012	.048	.011
3	.125	.022	.078	.025	.050	.016	.054	.010
4	.094	.020	.055	.022	.032	.021	.031	.010
5	.016	.036	.068	.023	.028	.018	.090	.020
6	(b)							
7	.034	.034	.065	(b)	.045	.016	.062	.022
8	.064	.029	.085	.011	.029	.015	.055	.019
9	.082	.015	.066	.028	.071	.018	.059	.018

= Questionable because of split discontinuity effect

<sup>a</sup> Location of discontinuity from split in sleeve

<sup>b</sup> Damaged; did not read

# PHASE I-TASK 3-COLDWORK PROCESS FOR STEEL

SPECIMEN 3F1 TEST 1 DATE 10/26/72

MATERIAL 300 M steel (280/300 ksi) MANDREL MATERIAL Vascojet 'MA'

MATERIAL STACKUP 3/8 inch MANDREL TAPER (IN./IN.) 0.015

NOMINAL HOLE SIZE (IN.) 0.364 and 0.358 MANDREL MAX DIA (IN.) 0.3538 (start)

COLDWORK PROCESS Pull SLEEVE THICKNESS (IN.) 0.0105

LUBRICATION (SLEEVE) Fel Pro 300

Hole no.	Hole diameter (in.)		Theoretical coldwork diameter expansion (in.) <sup>a</sup>	Pull force (lb)	Sleeve throat (in.)	Retained coldwork diameter expansion (in.)	Mandrel diameter loss (in.)	Remarks (tool life, operational success, etc.)
	Before coldwork	After coldwork						
A1	0.3635	0.3670	0.0113	2600	0.0004	0.0035	None	Mandrel had deep center.
A2	0.3635	0.3660	0.0113	2340	0.0004	0.0025	None	
A3	0.3635	0.3660	0.0113	2520	0.0004	0.0025	0.0002	
E1	0.3580	0.3635	0.0166	2620	0.0006	0.0045	0.0004	
E2	0.3585	0.3635	0.0157	2630	0.0010	0.0045	0.0004	
E3	0.3585	0.3635	0.0153	2560	0.0015	0.0045	None	
								Difficulty removing sleeve

<sup>a</sup> Does not include allowance for mandrel diameter decrease or sleeve throat

# PHASE I - TASK 3 - COLDWORK PROCESS FOR STEEL

SPECIMEN 3F1 TEST 2 DATE 10/26/72

MATERIAL: 300 M steel (280/300 ksi) MANDREL MATERIAL: Vascojet 'MA'

MATERIAL STACKUP: 3/4 inch MANDREL TAPER (IN./IN.): 0.015

NOMINAL HOLE SIZE (IN.): 0.364 and 0.3680 MANDREL MAX DIA (IN.): 0.3528 (start)

COLDWORK PROCESS: Pull SLEEVE THICKNESS (IN.): 0.0105

LUBRICATION (SLEEVE): Fel Pro 300

Hole no.	Hole diameter (in.)		Theoretical coldwork diameter expansion (in.) <sup>a</sup>	Pull force (lb)	Sleeve thinout (in.)	Retained coldwork diameter expansion (in.)	Mandrel diameter loss (in.)	Remarks (tool life, operational success, etc.)
	Before coldwork	After coldwork						
A4	0.3630	0.3650	0.0108	3600	0.0010	0.0020	None	(Sleeve could not be removed from hole)
A5	0.3630	0.3655	0.0108	3230	0.0005	0.0025	None	
A6	0.3630	0.3655	0.0108	3280	0.0005	0.0025	None	
E4	0.3580	See remarks	0.0158	4670			0.0006	
E5	0.3580	0.3625	0.0152	5670	0.0010	0.0045	0.0001	
E6	0.3575	0.3630	0.0151	5140	0.0010	0.0045	None	

<sup>a</sup> Does not include allowance for mandrel diameter decrease or sleeve thinout

# PHASE I-TASK 3-COLDWORK PROCESS FOR STEEL

SPECIMEN 3F1 TEST 3 DATE 10/26/72

MATERIAL 300 M steel (280,300 ksi) MANDREL MATERIAL A1S1 9260

MATERIAL STACKUP: 3/4 inch MANDREL TAPER (IN./IN.): 0.015

NOMINAL HOLE SIZE (IN.) .3640 and .3580 MANDREL MAX DIA (IN.): 0.3538 (start)

COLDWORK PROCESS: Pull SLEEVE THICKNESS (IN.) 0.0105

LUBRICATION (SLEEVE): FelPro 300

Hole no.	Hole diameter (in.)		Theoretical coldwork diameter expansion (in.) <sup>a</sup>	Pull force (lb)	Sleeve throat (in.)	Retained coldwork diameter expansion (in.)	Mandrel diameter loss (in.)	Remarks (tool life, operational success, etc.)
	Before coldwork	After coldwork						
A7	0.3630	0.3655	0.0118	3940	0.0010	0.0025	0.0004	Sleeve could not be removed
A8	0.3630	0.3660	0.0114	3420	0.0010	0.0030	0.0004	
B1	0.3630	0.3650	0.0110	3740	0.0010	0.0020	0.0001	
E7	0.3580	0.3625	0.0159	4320	0.0015	0.0045	0.0007	
E8	0.3585	0.3625	0.0147	4800	0.0015	0.0050	0.0002	
F1	0.3580		0.0150	4460			None	

<sup>a</sup> Does not include allowance for mandrel diameter decrease or sleeve throat

## 126

3F1

4

## TEST

3F1

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300 M steel (280/300 ksi)

300 M s<sup>-1</sup>

**3/4 inch**

31.

0.3580

0.

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Fel Pro 300

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## NOTES

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<sup>d</sup> Does not include allowance for mandrel diameter decrease or sleeve thinout

# PHASE I - TASK 3 - COLDWORK PROCESS FOR STEEL

SPECIMEN Fatigue coupon TEST 5 DATE 11/6/72

MATERIAL: 4340 'M' (270/300 ksi) MANDREL MATERIAL: Vascojet 'MA'

MATERIAL STACKUP 0.20 inch

MANDREL TAPER (IN./IN.) 0.015

NOMINAL HOLE SIZE (IN.) 3/8

MANDREL MAX DIA (IN.) 0.3521 (at start)

COLDWORK PROCESS Pull

SLEEVE THICKNESS (IN.) 0.0105

LUBRICATION (SLEEVE): FelPro 300

Hole no.	Hole diameter (in.)		Theoretical coldwork diameter expansion (in.) <sup>a</sup>	Pull force (lb)	Sleeve thinout (in.)	Retained coldwork diameter expansion (in.)	Mandrel diameter loss (in.)	Remarks (tool life, operational success, etc.)
	Before coldwork	After coldwork						
1	0.3630	0.3656	0.0101	1880	0.0013	0.0026	None	Mandrel previously used for steel pull testing.
2	0.3540	0.3605	0.0191	3000	0.0035	0.0065	None	
3	0.3540	0.3615	0.0190	2175	0.0025	0.0075	None	
4	0.3540	0.3606	0.0190	2220	0.0025	0.0066	None	

<sup>a</sup> Does not include allowance for mandrel diameter decrease or sleeve thinout

# PHASE I - TASK 3 - COLDWORK PROCESS FOR STEEL

SPECIMEN Fatigue coupon TEST 6 DATE 11/6/72

MATERIAL: 4340 M\* (270-300 ksi) MANDREL MATERIAL: AISI 9260  
 MATERIAL STACKUP: 0.20 inch MANDREL TAPER (IN./IN.): 0.015  
 NOMINAL HOLE SIZE (IN.): 3/8 MANDREL MAX DIA (IN.): 0.3520  
 COLDWORK PROCESS: Pull SLEEVE THICKNESS (IN.): 0.0105  
 LUBRICATION (SLEEVE): Fel Pro 300

Hole no.	Hole diameter (in.)		Theoretical coldwork diameter expansion (in.) <sup>a</sup>	Pull force (lb)	Sleeve thinout (in.)	Retained coldwork diameter expansion (in.)	Mandrel diameter loss (in.)	Remarks (tool life, operational success, etc.)
	Before coldwork	After coldwork						
1	0.3540	0.3605	0.0190	2335	0.0030	0.0065	None	Sleeve slid in jaws & crippled part of sleeve failed
2	0.3530	0.3573	0.0200	2875	0.0035	0.0043	0.0002	
3	0.3530	0.3600	0.0198	2700	0.0030	0.0070	None	

<sup>a</sup> Does not include allowance for mandrel diameter decrease or sleeve thinout

## PHASE 1 -- TASK 3 -- COLDWORK PROCESS FOR STEEL

SPECIMEN 3F1 TEST 7 DATE: 11/21/72

MATERIAL: 300 M steel (280/300 ksi)

MATERIAL STACKUP: 3/4 inch MANDREL TAPER (IN / IN): 0.015

NOMINAL HOLE SIZE (IN.): 3/8

COLDWORK PROCESS: PULL SLEEVE THICKNESS (IN.) 0.0105

LUBRICATION (SLEEVE): Fel Pro 300[illegible]

<sup>a</sup> Does not include allowance for mandrel diameter decrease or sleeve thinout

# PHASE I - TASK 3 - COLDWORK PROCESS FOR STEEL

SPECIMEN 3F1 TEST 8 DATE 11/21/72

MATERIAL: 300 M steel (280/300 ksi) MANDREL MATERIAL: AISI 9260

MATERIAL STACKUP: 3/8 inch MANDREL TAPER (IN./IN.): 0.015

NOMINAL HOLE SIZE (IN.): 3/8 MANDREL MAX DIA (IN.): 0.3518

COLDWORK PROCESS: Pull SLEEVE THICKNESS (IN.): 0.0105

LUBRICATION (SLEEVE): Fel Pro 300

Hole no.	Hole diameter (in.)		Theoretical coldwork diameter expansion (in.) <sup>a</sup>	Pull force (lb)	Sleeve thinout (in.)	Retained coldwork diameter expansion (in.)	Mandrel diameter loss (in.)	Remarks (tool life, operational success, etc.)
	Before coldwork	After coldwork						
1	0.3500	-	0.0230	4080	-	-	0.0050	Mandrel diameter decreased too much for production process

<sup>a</sup> Does not include allowance for mandrel diameter decrease or sleeve thinout

### ALLOY 300M\* (Ultra-High Strength Steel)

ALLOY 300M is an alloy steel offering a combination of hardenability, ductility and toughness at tensile strengths from 280000 to 320000 psi.

\* U.S. Pat. 2,791,500

#### Composition:

Carbon	0.40-0.45
Manganese	0.65-0.90
Silicon	1.45-1.80
Nickel	1.65-2.00
Chromium	0.65-0.90
Molybdenum	0.30-0.45
Vanadium	0.05 min.
Phosphorus	0.025 max.
Sulphur	0.025 max.
Iron	Remainder

#### Physical Constants:

Density, lb./cu. in.	0.283
Thermal coef. expansion/°F. x 10 <sup>-6</sup> (0-200°F.)	6.3
Thermal conductivity, BTU./ft <sup>2</sup> /in./hr./°F.	260
Specific heat, BTU./lb./°F.	0.107
Modulus of elasticity, psi x 10 <sup>6</sup>	29.30

#### PROPERTIES

Table 1—EFFECT OF TEMPERING TEMPERATURE

(1" rd., oil quenched from 1575°F.)

Tempering Temperature °F.	Tensile Strength psi	Yield Strength psi (0.2%)	Charpy Impact ft. lbs.	Elongation % in 2"	Reduction of Area %	Brinell Hardness
200	340000	180000	13.0	6.0	10.0	575
400	310000	240000	16.0	7.0	27.0	555
500	297000	242000	18.0	8.0	32.0	540
600	289000	245500	22.0	9.5	34.0	525
700	280000	235000	17.5	9.0	32.0	500
800	260000	215000	10.0	8.5	23.0	425

Table 2—TYPICAL MECHANICAL PROPERTIES—FORGING

(Quenched in oil and tempered at 500°F.)

	Longitudinal	Transverse
Tensile strength, psi	297000	296000
Notch tensile strength, psi	303000	262000
Yield strength, psi (0.2%)	242000	239000
Elongation, % in 2"	8.0	4.0
Reduction of area, %	23.0	9.4
Charpy impact, ft. lbs. (V-notch)		
at room temp.	18	9
at -65°F.	15	7
Bend test*		
Load, lbs.	10200	9650
Outside angle, deg.	35	25

\* Load applied at center of 7/16" dia. x 5" long specimen supported near end.

Table 3—TYPICAL PROPERTIES OF WELDED TUBES

(5 1/2" dia. x 1/4" wall, flash butt welded tubes, oil quenched and tempered at 400°F.)

	Parent Metal	Across the Weld
Tensile strength, psi	302500	285600
Notch strength, psi	270000	246000
Elongation, % in 2"	9	3
Reduction of area, %	18	7
Charpy impact, ft. lbs. (V-notch)		
at room temp.	20	19
at -65°F.	18	14
Bend Test*		
Max. load, lbs.	9800	8900
Outside bend angle, deg.	35	25

\* Load applied to the center of 7/16" dia. by 5" long rounds supported near ends.

Table 4—EFFECT OF MASS ON TENSILE PROPERTIES\*

(Heat treated by normalizing at 1700°F., oil quenching from 1575°F. and tempering at 600°F.)

Bar Diameter inches	Tensile Strength psi	Yield Strength psi (0.2%)	Elongation % in 2"	Reduction of Area %
1	280000	245500	9.5	34.1
3	281000	246000	9.5	35.0
5 1/4	308000	261000	7.3	22.3

\* Heat treated in full section

**Table 5--EFFECT OF MASS ON IMPACT PROPERTIES\***  
(Heat treated by normalizing at 1650°F., oil quenching from 1575°F. and tempering at 600°F.)

Bar Diameter inches	Izod Impact ft. lbs. at +70°F.	Charpy Impact V-Notch, ft. lbs.		
		+70°F.	-50°F.	-100°F.
1	23	72	19	18
3	15	19	14	9
5 3/4	12	9	7	5

\* Heat treated in full section.

**Table 6---NOTCH TENSILE TESTS**  
(4 1/2" squares, oil quenched and tempered at 600°F.)

	0.3" Diameter	0.5" Diameter
K factor = 10 Longitudinal	320000	275000
Transverse	315000	245000
K factor = 5 Longitudinal	345000	307000
Transverse	312000	312000
K factor = 3 Longitudinal	385000	358000
Transverse	385000	335000

(Stress concentration "K" factors were varied by control of notch root radius. The factor for the sharp notch—less than 0.001" radius—is 10.

**Table 7—TYPICAL MECHANICAL PROPERTIES—CAST**  
(0.36C sand cast keel blocks 1" x 1" x 6")

	Heat Treat A	Heat Treat B
Tensile strength, psi	257500	262000
Yield strength, psi (0.1%)	221250	221750
Elongation, % in 2"	5.8	5.9
Reduction of area, %	10.6	10.8
Charpy impact, ft. lbs. (V-notch) R. T.	10.5	11
0°F.	10	10
-50°F.	10	8
-100°F.	8	8

Heat Treat A—Austenitized at 1650°F. for one hour, transferred to a furnace at 1350°F., held at 1350°F. for 30 minutes, quenched in oil and double tempered at 600°F. for 6 hours.

Heat Treat B—Austenitized at 1650°F. for one hour, transferred to a furnace at 1350°F., held at 500°F. for 5 minutes, air cooled, double tempered at 600°F. for 6 hours.

#### Heat Treatment:

**CRITICAL POINTS:** Ac<sub>1</sub> 1400°F. Ar<sub>1</sub> 650°F.  
Ac<sub>3</sub> 1480°F. Ar<sub>3</sub> 785°F.

(400°F./hr. heating and cooling rate)

**ANNEALING:** Heat to about 1430°F. and equalize, cool 10°F./hr. to 1200°F., 20°F./hr. to 900°F. and air cool for 241 Brinell maximum. (Produces a spheroidized structure.)

**NORMALIZING:** Heat to about 1700°F., air cool. Recharge in furnace before reaching room temperature.

**HARDENING:** Heat to about 1600°F., quench in oil, temper at 500-600°F. Double tempering is advisable.

(It is not recommended for any other tempering temperature. This range produces maximum yield strength and maximum impact strength simultaneously. Tempering on either side of the recommended range results in a serious deterioration of mechanical properties.)

#### Machinability:

Machinability rating of annealed material is 45% of cold-rolled B1112 screw machine stock. Can be machined without difficulty up to 250 Brinell. A partially spheroidized structure obtained by normalizing and drawing at 1200 deg. F. is best for optimum machinability.

High speed steel cutting tools should be ground to R-12 deg. side rake, 6-10 deg. back rake, 7-9 deg. side relief, 7-9 deg. end relief, R-12 deg. end cutting-edge angle, about 15 deg. side cutting-edge angle, and a nose radius of about 10% of depth of cut. Sintered carbide cutting tools should be ground to 4-9 deg. side rake, 0-10 deg. back rake, 6-10 deg. side relief, 6-12 deg. end relief, 8-13 deg. end cutting-edge angle, 0-20 deg. side cutting-edge angle, and a nose radius equal to 1/32 inch.

When machining stock around 200 Brinell hardness with high speed steel cutting tools use cutting speeds of 70 sfpm with feed of 0.060 in. rev. and depth of cut of 1/32 inch; 120 sfpm with feed of 0.015 in. rev. and depth of cut of 1/32 inch. 60 sfpm with feed of 0.030 in. rev. and 1/4 inch depth of cut. With sintered carbide cutting tools use cutting speeds of 260 sfpm with feed of 0.060 in. rev. and depth of cut of 1/32 inch, 470 sfpm with feed of 0.015 in. rev. and depth of cut of 1/32 inch. 205 sfpm with feed of 0.030 in. rev. and depth of cut of 1/4 inch.

#### Manufacturers:

Various alloy steel mills (licensed).

#### Workability:

Forge at 1950-2200°F. and allow to cool in air in a dry place. Forging should not be continued below 1700°F.

#### Weldability:

Good welding characteristics. Can be readily gas or arc welded. Welding rod of the same composition shall be used. In arc welding use a coated welding rod. The retarded grain growth during welding minimizes the normal ill-effects produced by grain coarsening. As the steel has air hardening properties the part after the welding shall be either annealed or normalized and drawn.

#### General Characteristics:

Tough, shock and impact resistant. Has best combination of ductility, toughness, and strength. High fatigue and creep resistant. This steel has air hardening properties and is especially free of temper-brittleness. Maintains good strength properties at elevated temperatures. Wear and abrasion resistant in hardened condition. The high depth hardness is reflected in excellent torque properties. Recommended for heavy duty, high-strength applications.

The most desirable properties of this steel are obtained by using a 600°F. temper after the oil quench. This treatment produces the best yield to tensile strength ratio and the best impact strength for all sizes tested. As shown by the impact data, the steel as tempered at 600°F. does not show any definite transition temperature range. There is a regular decrease in impact strength with decreasing temperature in the manner of 9% nickel steel.

Since tempering above 600°F. is not recommended, this steel should not be employed for service at higher temperatures. The hardenability of 300-M is so great that it may be heat treated in heavy sections without impairment of its properties. The Jominy hardenability curve, being essentially horizontal for its full length, indicates that the hardenability is too great to be usefully evaluated by this test.

#### Forms Available:

Billets, bars, rods, forgings, sheet, strip, plate and castings

#### Applications:

Aircraft landing gears, airframe parts, high strength bolts, nutting wing fasteners and pylon parts, carbide-bit bodies, drop forgings for various applications, axles, gears, shafting, pressure vessels, oil-well perforating guns.

### AISI 9260 (Spring Steel)

Published by  
Engineering Alloys Digest, Inc.  
Upper Montclair, New Jersey

AISI 9260 is an oil-hardening type of spring steel and tool steel recommended for repeated and severe impact service. It is also used for heavy duty, shock resistant machine parts.

#### Composition:

	9260	9260H
Carbon	0.56-0.64	0.55-0.65
Manganese	0.75-1.00	0.65-1.10
Silicon	1.80-2.20	1.70-2.20
Phosphorus*	0.035 max	0.040 max
Sulphur*	0.040 max	0.040 max
Iron	Remainder	Remainder

\*Phosphorus and sulphur are 0.040 max in open hearth steel and 0.025 max in electric furnace steel.

#### Physical Constants:

Density, lb/cu.in.	0.283
Thermal conductivity, Btu/ft <sup>2</sup> /hr/°F (212°F)	27
Thermal coef. expansion/°F (70-1200°F) x 10 <sup>-6</sup>	8.1
Specific heat, Btu/lb·°F	0.10-0.11
Electrical resistivity, microhm-cm (68°F)	20
Modulus of elasticity, psi x 10 <sup>6</sup> (in tension)	29.0
(in torsion)	10.7

#### PROPERTIES

Table 1 — TYPICAL MECHANICAL PROPERTIES

	Normalized	Annealed
Tensile strength, psi	150000	118000
Yield strength, psi (0.2%)	80000	68000
Elongation, % in 2"	15	22
Reduction of area, %	30	46
Brinell hardness	311	241
Isod impact, ft. lbs.	5	5

Table 2 — TYPICAL HEAT TREATED PROPERTIES  
(1" Rd., normalized 1600°F., quenched in oil 1575°F., tempered)

Tempering Temperature °F.	Tensile Strength psi	Yield Strength psi (0.2%)	Elongation % in 2"	Reduction of Area %	Brinell Hardness	Isod Impact ft. lbs.
400	355000	330000	5	19	653	6
500	350000	330000	7	21	655	7
600	340000	325000	9	25	627	7
700	325000	280000	9.5	28	601	8
800	260000	228000	10	30	514	12
900	215000	193000	11	31	479	13
1000	187000	166000	12	32.5	368	14
1100	165000	144000	15	35	341	24
1200	148000	125000	17	40	311	35
1300	130000	103000	20	47	269	59

Table 3 — MASS EFFECT DATA  
(5.7 Grain Size, 0.61C, 0.82Mn, 2.11Si, 0.23Cr, 0.08Ni, 0.02Mo)  
(Bethlehem—Single best results)

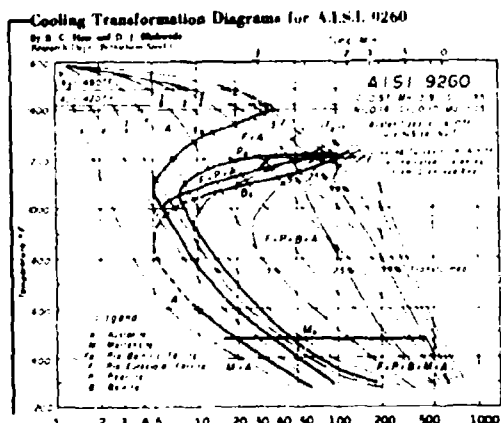
Size Inches	Tensile Strength psi	Yield Point psi	Elongation % in 2"	Reduction of Area %	Brinell Hardness	Isod Impact ft. lbs.
Annealed—(Heated to 1575°F., furnace cooled 20°F. hr. to 1280°F., air cooled)						
1	132250	67250	14.5	20.2	262	2.5
Normalized—(Heated to 1600°F., air cooled)						
1/2	166750	98250	15.3	35.8	331	4.0
1	161000	90750	14.7	25.5	321	4.0
2	159500	87250	13.7	30.5	311	4.0
4	144000	86750	4.2	5.9	295	5.0
Oil quenched from 1575°F., tempered at 900°F.						
1/2	230500	207000	10.7	25.7	441	5.7
1	224500	200750	9.2	24.6	444	6.0
2	202000	168250	9.5	22.7	401	6.5
4	173250	105500	4.5	4.5	341	5.5
Oil quenched from 1575°F., tempered at 1100°F.						
1/2	177750	155000	14.2	30.0	352	5.0
1	174250	147500	14.7	34.5	351	8.7
2	160250	130500	16.0	36.0	321	8.2
4	149000	94250	10.5	19.2	321	5.2

Table 4 — AS-QUENCHED HARDNESS DATA  
(Oil quenched from 1575°F.)

	Rockwell "C" Hardness			
	1/2" Rd.	1" Rd.	2" Rd.	4" Rd.
Surface	64	62	60	42
1/2" Radius	64	62	55	38
Center	64	62	50	37

**Table 3.- JOMINY HARDENABILITY - 9260H**  
(1/4" distance in 1/16 inch)

"J" distance	1	2	3	4	5	6	7	8	10	12	16	20	24	32
Rc max.	-	-	65	64	63	62	60	58	52	47	40	37	36	34
Rc min.	60	60	57	53	46	41	38	36	35	34	32	31	30	28



#### Heat Treatment:

Critical Points:  $A_c1$ , 1440°F  
 $A_c3$ , 1490°F  
 $A_r1$ , 1345°F  
 $A_r3$ , 1330°F

Anneal: Heat to 1525-1575°F, furnace cool.

Normalize: Heat to 1600-1650°F, quench.

Harden: Heat to 1575-1625°F, quench in oil, temper to desired hardness.

#### Machinability:

Machinability rating of mill annealed stock (187-255 Brinell) is about 45% of AISI B1112 steel. To obtain best machining properties, heat to 1400-1450°F, cool slowly to 1000°F, then air cool.

Cobalt high-speed steel or carbide-tipped cutting tools are recommended. High-speed steel turning tools should be ground to 8-10° side rake, 6-8° back rake, 7-9° side relief, 7-9° end relief, 10-14° end cutting-edge angle, 12-16° side cutting-edge angle, and a nose radius equal to 10% of depth of cut. Carbide-tipped tools should be ground to 6-10° side rake, 2-6° back rake, 8-10° side relief, 8-10° end relief, 8-10° end cutting-edge angle, 8-14° side cutting-edge angle, and a nose radius of 1/32 inch. For high-speed steel cutters use sulphurized or chlorinated cutting oils, but no cutting oil for carbide-tipped tools.

#### Specification Equivalents:

SAE 9260  
 QQ-S-624, F59260  
 QQ-S-474, Comp. F  
 ASTM A59, Gr. 9260  
 ASTM A331 Gr. 9260  
 ASTM A304, Gr. 9260H  
 MIL-S-6410 Comp. 5

#### Workability:

Forge from 2175°F. to 1750°F. It is subject to decarburization and should therefore not be held at the forging temperature longer than is necessary. After forging, the steel should be cooled slowly by burying in ashes, dry lime, silicel or other dry heat-insulation material.

#### Weldability:

The high carbon and silicon contents of this steel introduces difficulty in welding, which is, therefore, not recommended normally.

#### Corrosion Resistance:

This steel is better than plain carbon steel in industrial atmosphere and about the same when continuously exposed to moisture. If salts are present, corrosion is increased. It is attacked readily by acids, but resistant to alkalis at ordinary temperatures.

#### General Characteristics:

AISI 9260 is recommended for heavy duty springs and for shock resisting parts in which a combination of high ductility with hardness is required. The combined qualities of extremely high strength together with toughness gives this steel the ability to withstand repeated and severe impacts. It is primarily an oil-hardening steel. It may be quenched in water with satisfactory results, but care should be taken if the part has drastic dimensional change or sharp corners. The higher oil-quenching temperature improves the strength, ductility, and shock-resistance. It has good wear-resistance and maximum shock-resistance for hardnesses under Rockwell C58.

Although it is not classed as a non-deforming steel, it will hold size and shape reasonably well during heat treatment, if normal precautions are used in its application and treatment. Where freedom from distortion is of primary importance, the parts should always be oil-quenched rather than water-quenched.

It decarburizes more freely than other tool steels when heated for forging, annealing, or heat treating. This is due to its high silicon and molybdenum content. Care should be exercised during heating to protect it from decarburization. This steel is less notch sensitive than either carbon steel or chromium-vanadium alloy steel.

#### Form Available:

Billets, bars, rods, forgings.

#### Applications:

Heavy duty springs, shear blades, pneumatic tool, punches, shanks for carbide tools, machine parts subject to shock, chisels, caulking tools and all types of severe or unusual service involving drastic or repeated impact at atmospheric temperatures.

#### Manufacturers:

Practically all alloy steel mills.

#### VASCOJET M-A (CVM) (Ultra High Strength Steel)

Published by  
Engineering Alloy Digest, Inc.  
Upper Merion, New Jersey

Vascojet M-A (CVM) is an ultra high-strength alloy steel capable of reaching tensile strength values up to 360,000 psi and maintaining high strength levels at operating temperatures to 1000 deg. F. It combines extremely high strength with ductility, toughness, fatigue and heat resistance.

#### Composition:

Carbon	0.50-0.55
Tungsten	
Molybdenum	
Chromium	
Vanadium	
Iron	Remainder
Total	12.0

#### Physical Constants:

Specific gravity	7.92
Density, lb/cu.in.	0.285
Thermal coef. expansion/°F x 10 <sup>-6</sup> (80-1000°F)	6.4
Modulus of elasticity, psi x 10 <sup>6</sup>	
at 70°F	31.0
at 400°F	28.8
at 1000°F	24.0

#### PROPERTIES

**Table 1 - TYPICAL HEAT TREATED PROPERTIES**  
(Standard 0.250" round buttonhead tensile specimens quenched from 2050 deg. F. in salt at 1050 deg. F. and triple tempered (2+2+2 hours) as indicated.)

Tempering Temperature °F	Tensile Strength psi	Yield Strength psi (0.2%)	Elongation % in 2"	Reduction of Area %	Rockwell Hardness "C"	True Fracture Stress psi
975	361700	292600	6.0	20.0	60.9	430500
1000	351600	292600	8.0	33.4	59.9	433500
1025	345800	292400	7.0	34.1	59.5	440200
1050	344400	277700	7.8	33.2	58.6	435200
1075	321800	280200	6.5	31.0	57.3	398500
1100	305200	266500	6.5	28.5	56.1	378700
1150	253400	215500	7.0	25.2	50.4	311200
1200	200900	158500	9.0	33.0	40.9	259200
1300	144000	105400	14.0	48.4	33.5	226700

**Table 2 - TYPICAL TENSILE PROPERTIES AT 350 ksi T.S.**  
(Bar heat treated to 350000 psi tensile strength)

Tensile strength, psi	350000
Yield strength, psi (0.2%)	290000
Elongation, % in 2"	8
Reduction of area, %	33
Rockwell hardness	C60

**Table 3 - TYPICAL AUSFORMED PROPERTIES\***  
(Austenite deformed 91% at 1100°F before conventional quenching and tempering)

Tempering Temperature °F	Tensile Strength psi	Yield Strength psi (0.2%)	Elongation % in 2"	Reduction of Area %
700	465000	425000	7	22
800	460000	425000	7	25
1000	455000	410000	7	33
1100	435000	390000	9	39

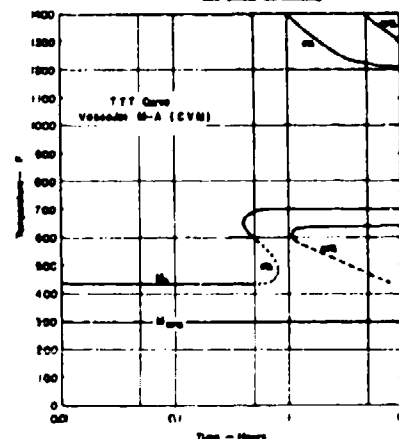
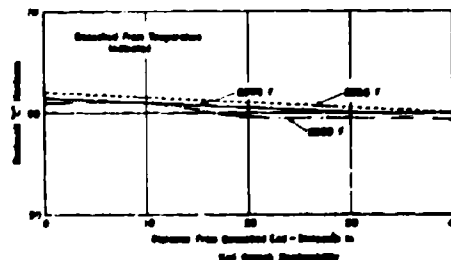
\*From Justusson and Zackay

**Table 4 - IMPACT PROPERTIES**

Rockwell Hardness "C"	Izod Unnotched ft. lbs.	Charpy Unnotched ft. lbs.	Charpy V-Notch ft. lbs.
57.5	120 + (stops beam)	264 + (stops beam)	13
59.0	120 + (stops beam)	264 + (stops beam)	12
61.0	120 + (stops beam)	264 + (stops beam)	8

**Table 5 - TYPICAL ANNEALED PROPERTIES**

Tensile strength, psi	95000
Yield strength, psi (0.2%)	48000
Elongation, % in 2"	25
Reduction of area, %	55
Rockwell hardness	B89-93



**Table 6 - FATIGUE PROPERTIES**

Stress, psi	No. of Cycles
210,000	33,000
170,000	332,000
160,000	768,000
150,000	1,167,000
145,000	1,457,000
140,000	Stopped at 106,000,000

**Table 7 - EFFECT OF TEST TEMPERATURE ON THE TENSILE PROPERTIES**  
(Standard 0.505" round tensile specimens austenitized in salt at 2050°F for 5 minutes, salt quenched at 1050°F, and triple tempered (2+2+2 hours) as indicated. Average of two tests per condition.)

Testing Temperature °F	Tempering Temperature °F	Yield Strength psi (0.2%)	Tensile Strength psi	Reduction of Area %	Elongation % in 2"
500	1000	249200	317300	37.8	6.3
600	1000	255200	308600	37.2	5.8
800	1000	241600	292900	28.7	5.4
900	1000	221400	278600	30.9	5.9
1000	1000	204300	259000	24.9	5.4
500	1075	245000	289200	39.5	6.0
600	1075	229700	280500	31.7	6.3
800	1075	233500	264200	30.5	6.1
900	1075	206200	251300	38.2	5.7
1000	1075	183000	230100	28.8	6.3

**Heat Treatment:**

**Anneal:** Heat to 1600-1650 deg. F, cool slower than 50 deg. F per hour to 1000 deg. F, then more rapidly to room temperature.

**Hardening:** Preheat at 1550 deg. F, raise temperature rapidly to 2025-2050 deg. F in a protective atmosphere, hold 5-10 minutes at temperature, quench in air, salt, or oil, temper at 950-1150 deg. F. Double or triple tempering is recommended (2 + 2 + 2 hours).

(Phase changes: The steel transforms on slow cooling from austenite to spheroidite, A<sub>1</sub>—1380 to 1430°F.

Martensite start temperature, M<sub>s</sub>, is 430°F.)

**Stress Relief:** Heat at 875-950°F for 2-4 hours; for finished heat treated parts after grinding, machining or straightening.

**Machinability:**

Rough machining is generally performed on material in the fully annealed condition in much the same manner as any 0.50% C alloy steel.

Single point turning tools of high speed steel should be ground to 8-12° side rake, 6-10° back rake, 7-10° side relief, 7-10° end relief, 8-15° end cutting-edge angle, 12-18° side cutting-edge angle and a nose radius equal to 10% of cut depth. Sintered carbide-tipped tools should be ground to 4-12° side rake, 2-5° back rake, 5-10° side relief, 5-10° end relief, 8-12° end cutting-edge angle, 10-16° side cutting-edge angle and a 1/32" nose radius.

Use sulphurized or chlorinated oils containing sulphur as lubricants with high speed steel cutters.

**Workability:**

**Forging:** Start at 1950 to 1900°F and finish at 1650°F. It should be reheated as often as necessary to prevent forging too cold. Because of its air-hardening properties, it is very necessary that this steel be cooled slowly after forging to prevent the formation of stress cracks. After forging, the material may be returned to a hot furnace and cooled slowly with the furnace, or may be buried in some insulating material such as lime, mica or silocel.

**Forming:** This alloy in the fully annealed condition can be readily formed by all common methods. Straightening can be performed either during cooling from austenitizing or during heating for tempering.

**Weldability:**

Preheat at 500-1000°F, weld with inert gas shielded arc or coated electrodes; maintain temperature above 600°F, cool slowly in furnace or insulating medium. Welded parts have shown excellent weldability with weld metal strength and ductility equal to or greater than the parent metal. Because of its hardenability, welding requires preheating and post-heating and generally is followed by an anneal.

Welded parts are usually slowly cooled to 200°F, followed by immediate tempering to 1250-1400°F, for softening, to permit final straightening and sizing without cracking.

**Corrosion Resistance:**

General corrosion resistance of this steel is low and surface protection is required. For room temperature applications, conventional paint, plating, vapor deposition, and other coatings

may be used. For elevated temperature applications, aluminum silicone paint, nickel-cadmium diffusion plating, nickel-zinc plate, etc. may be used.

Hydrogen embrittlement may occur after hydrogenating treatment of the high strength conditions at high strength levels. Approved plating methods should be followed by baking at temperatures ranging from 375°F for 24 hours (for low heat resistant plate) to 950°F for heat resisting plate. At the upper end of the operating temperature range, protection is required if slight oxidation to a tight scale is not permissible.

**Pickling:**

Heat treated parts should be cleaned by mechanical methods. Pickling or cathodic cleaning are not permissible.

**General Characteristics:**

Vascojet M-A (CVM) is a consumable vacuum arc melted, high strength alloy steel providing more ductility and a smaller differential between longitudinal and transverse mechanical properties. It can be air, salt or oil hardened depending on the section thickness. Triple tempering produces stress relief combined with maximum hardness because tempering is done in the secondary hardening temperature range, i.e., the range in which the steel develops a higher hardness than at a lower temperature; hydrogen, which can cause embrittlement when tensile strength exceeds 200,000 psi, is rapidly removed and strength is not lowered; retained austenite is transformed, reducing the danger of subsequent transformation to martensite with accompanying high stresses during service.

Vascojet M-A (CVM) is a high-strength structural steel offering tensile strength values up to 360,000 psi at room temperature and high strength levels at operating temperatures to 1000°F. It is readily machined and can be formed by all standard methods of fabrication. In order to achieve maximum strength and ductility, it is recommended that this alloy be ordered in the CVM (consumable vacuum melted) grade. Experience indicates that CVM melting, with subsequent removal of dissolved gases and reduction of inclusions to a minimum, improves transverse type properties by factors of two or three to one. This alloy assures outstanding fatigue strength due to the fact that it offers the full advantage of secondary hardening phenomena.

This steel is highly magnetic, but becomes nonmagnetic at temperatures above 1400 to 1500°F. The damping capacity is  $1.3 \times 10^{-4}$  logarithmic decrement.

Vascojet M-A has been found to respond quite satisfactorily to the ausforming process. Tensile strength levels in excess of 450,000 psi with quite respectable ductility are possible. The deformation of metastable austenite before quenching and tempering enhances strength and hardness.

**Forms Available:**

Billets, forgings, sheet, plate, bars and wire.

**Applications:**

Fasteners, airframes, rocket motor cases, high speed rotors, lightweight axles, gears, shafting, pressure vessels, helicopter rotors, engine mounts, turbine components, and nuclear applications.

**Manufacturer:**

Vanadium Alloys Steel Corp.  
Latrobe, Pennsylvania

Best Available Copy

# PHASE I-TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 1A DATE: 1/4/73

## TEST CONDITIONS

### Specimen Description

Material: <u>2024-T851</u>	Hole spacing (in.): <u>1-1/8</u>
Material gage (in.): <u>0.375</u>	Nominal hole size (in.): <u>3/8</u>
Size (L x W)(in.): <u>15 x 1.5</u>	Edge margin: <u>0.75 in.</u>
Number of holes: <u>12</u>	

### Coldwork Information

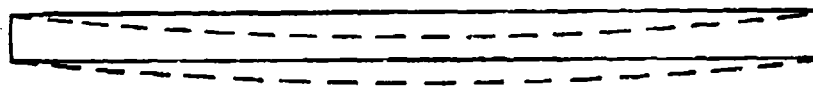
Coldwork process: <u>Sleeve</u>
Mandrel taper (in./in.): <u>0.045</u>
Mandrel diameter (in.): <u>0.3537</u>
Expansion (in.): <u>0.0185</u>

## RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.0017</u>
Edge bulge between holes, average (in.):	<u>0.001</u>
<sup>a</sup> Bow after coldwork (in.):	<u>+0.025</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>+0.0085</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>None</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.0085 in 12.375</u>
Specimen growth after ream (in.):	<u>0.0085 in 12.375</u>
Specimen growth after countersink (in.):	<u>0.0080 in 12.375</u>

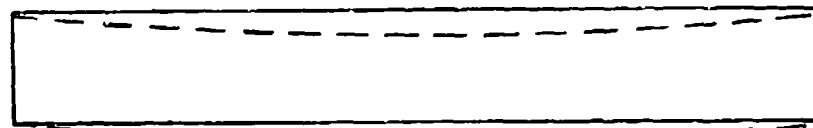
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
(-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion:



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

# PHASE I--TASK 4A--EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 2A DATE: 1/4/73

## TEST CONDITIONS

### Specimen Description

Material:	<u>2024-T851</u>	Hole spacing (in.):	<u>1-1/2</u>
Material gage (in.):	<u>0.375</u>	Nominal hole size (in.):	<u>3/8</u>
Size (L x W)(in.):	<u>15 x 1.5</u>	Edge margin:	<u>0.75 in.</u>
Number of holes:	<u>9</u>		

### Coldwork information

Coldwork process:	<u>Sleeve</u>
Mandrel taper (in./in.):	<u>0.045</u>
Mandrel diameter (in.):	<u>0.3537</u>
Expansion (in.):	<u>0.0185</u>

## RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.0015</u>
Edge bulge between holes, average (in.):	<u>0.0005</u>
<sup>a</sup> Bow after coldwork (in.):	<u>+0.025</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>+0.018</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>None</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.0090 in 12</u>
Specimen growth after ream (in.):	<u>0.011 in 12</u>
Specimen growth after countersink (in.):	<u>0.010 in 12</u>

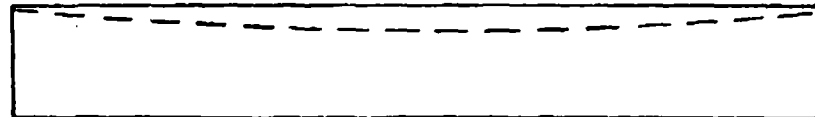
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
(-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance.

# PHASE I-TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 3A DATE: 1/4/73

## TEST CONDITIONS

### Specimen Description

Material: <u>2024-T851</u>	Hole spacing (in.): <u>1-1/8</u>
Material gage (in.): <u>0.375</u>	Nominal hole size (in.): <u>3/8</u>
Size (L x W)(in.): <u>15 x 1-1/8</u>	Edge margin: <u>0.563 in.</u>
Number of holes: <u>12</u>	

### Coldwork Information

Coldwork process: Sleeve  
Mandrel taper (in./in.): 0.045  
Mandrel diameter (in.): 0.3537  
Expansion (in.): 0.0185

## RESULTING DATA

Edge bulge at holes, average (in.): 0.0020  
Edge bulge between holes, average (in.): 0.0007  
<sup>a</sup>Bow after coldwork (in.): +0.055  
<sup>a</sup>Bow after ream and countersink (in.): +0.045  
<sup>b</sup>Edge distortion after coldwork (in.): 0.003  
<sup>c</sup>Specimen growth after coldwork (in.): 0.0165 in 12.375  
Specimen growth after ream (in.): 0.0150 in 12.375  
Specimen growth after countersink (in.): 0.0150 in 12.375

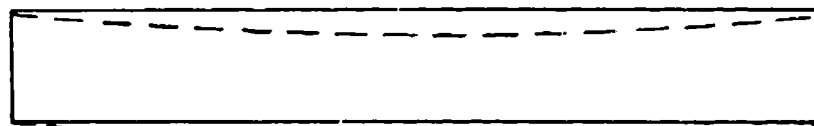
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
(-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

# PHASE I--TASK 4A--EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 4A DATE: 1/4/73

## TEST CONDITIONS

### Specimen Description

Material: <u>2024-T851</u>	Hole spacing (in.): <u>1-1/2</u>
Material gage (in.): <u>0.375</u>	Nominal hole size (in.): <u>3/8</u>
Size (L x W)(in.): <u>15 x 1-1/8</u>	Edge margin: <u>0.563 in.</u>
Number of holes: <u>9</u>	

### Coldwork Information

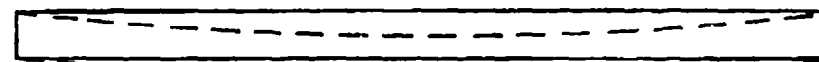
Coldwork process: Sleeve  
Mandrel taper (in./in.): 0.045  
Mandrel diameter (in.): 0.3537  
Expansion (in.): 0.018

## RESULTING DATA

Edge bulge at holes, average (in.): 0.0022  
Edge bulge between holes, average (in.): 0.0005  
<sup>a</sup>Bow after coldwork (in.): +0.051  
<sup>a</sup>Bow after ream and countersink (in.): +0.040  
<sup>b</sup>Edge distortion after coldwork (in.): 0.010  
<sup>c</sup>Specimen growth after coldwork (in.): 0.0165 in 12  
Specimen growth after ream (in.): 0.0150 in 12  
Specimen growth after countersink (in.): 0.0145 in 12

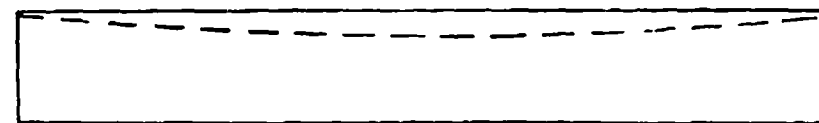
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
(-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

# PHASE I--TASK 4A--EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 7A DATE: 1/4/73

## TEST CONDITIONS

### Specimen Description

Material: <u>2024-T851</u>	Hole spacing (in.): <u>2-1/4</u>
Material gage (in.): <u>0.750</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W)(in.): <u>15 x 2-1/4</u>	Edge margin: <u>1.125 in.</u>
Numer of holes: <u>6</u>	

### Coldwork Information

Coldwork process: <u>Sleeve</u>
Mandrel taper (in./in.): <u>0.045</u>
Mandrel diameter (in.): <u>0.7145</u>
Expansion (in.): <u>0.030</u>

## RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.0035</u>
Edge bulge between holes, average (in.):	<u>0.0015</u>
<sup>a</sup> Bow after coldwork (in.):	<u>+0.009</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>+0.006</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>None</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.011 in 11.25</u>
Specimen growth after ream (in.):	<u>0.013 in 11.25</u>
Specimen growth after countersink (in.):	<u>0.013 in 11.25</u>

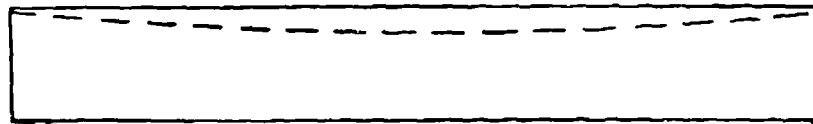
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
(-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

# PHASE I--TASK 4A--EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 8A DATE: 1/4/73

## TEST CONDITIONS

### Specimen Description

Material: <u>2024-T851</u>	Hole spacing (in.): <u>3.00</u>
Material gage (in.): <u>0.750</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W) (in.): <u>15 x 2-1/4</u>	Edge margin: <u>1.125 in.</u>
Number of holes: <u>4</u>	

### Coldwork Information

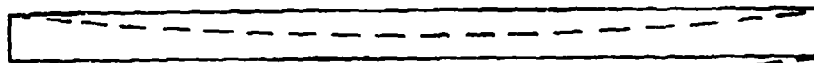
Coldwork process: <u>Sleeve</u>
Mandrel taper (in./in.): <u>0.045</u>
Mandrel diameter (in.): <u>0.7142</u>
Expansion (in.): <u>0.030</u>

## RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.004</u>
Edge bulge between holes, average (in.):	<u>None</u>
<sup>a</sup> Bow after coldwork (in.):	<u>+0.008</u>
<sup>d</sup> Bow after ream and countersink (in.):	<u>+0.008</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>None</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.0095 in 9</u>
Specimen growth after ream (in.):	<u>0.0115 in 9</u>
Specimen growth after countersink (in.):	<u>0.0120 in 9</u>

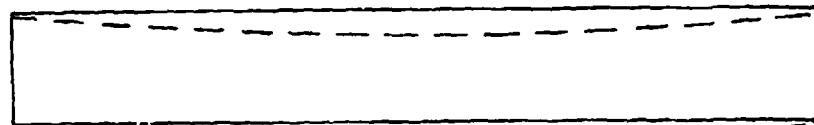
<sup>a</sup>Bow direction

Direction of coldwork



(+) indicates bow as shown in sketch  
(-) indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow.

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

# PHASE I--TASK 4A--EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 9A DATE: 1/4/73

## TEST CONDITIONS

### Specimen Description

Material: <u>2024-T851</u>	Hole spacing (in.): <u>2-1/4</u>
Material gage (in.): <u>0.750</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W)(in.): <u>15 x 3</u>	Edge margin: <u>1.50 in.</u>
Numer of holes: <u>6</u>	

### Coldwork Information

Coldwork process: <u>Sleeve</u>
Mandrel taper (in./in.): <u>0.045</u>
Mandrel diameter (in.): <u>0.7142</u>
Expansion (in.): <u>0.030</u>

## RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.003</u>
Edge bulge between holes, average (in.):	<u>0.0015</u>
<sup>a</sup> Bow after coldwork (in.):	<u>+0.006</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>+0.004</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>None</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.0063 in 11.25</u>
Specimen growth after ream (in.):	<u>0.0065 in 11.25</u>
Specimen growth after countersink (in.):	<u>0.0070 in 11.25</u>

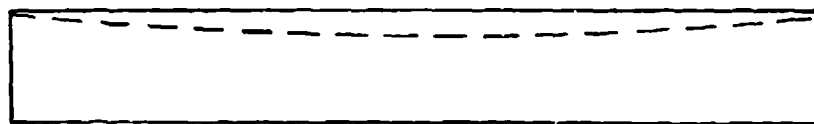
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
(-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance.

# PHASE I- TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 10A DATE: 1/4/73

## TEST CONDITIONS

### Specimen Description

Material: <u>2024-T851</u>	Hole spacing (in.): <u>3.00</u>
Material gage (in.): <u>0.750</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W)(in.): <u>15 x 3</u>	Edge margin: <u>1.50 in.</u>
Number of holes: <u>4</u>	

### Coldwork Information

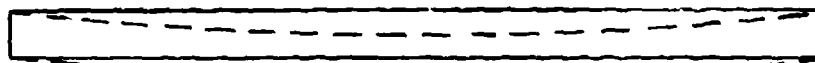
Coldwork process: <u>Sleeve</u>
Mandrel taper (in./in.): <u>0.045</u>
Mandrel diameter (in.): <u>0.7142</u>
Expansion (in.): <u>0.030</u>

## RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.0025</u>
Edge bulge between holes, average (in.):	<u>None</u>
<sup>a</sup> Bow after coldwork (in.):	<u>+0.006</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>+0.004</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>None</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.0045 in 9</u>
Specimen growth after ream (in.):	<u>0.0036 in 9</u>
Specimen growth after countersink (in.):	<u>0.0035 in 9</u>

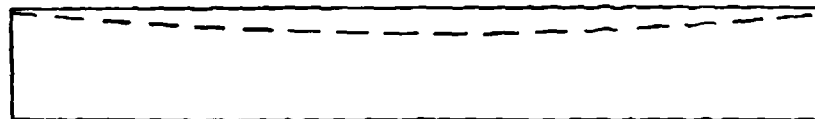
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
(-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance.

# PHASE I - TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 1T DATE: 1/6/73

## TEST CONDITIONS

### Specimen Description

Material: <u>Ti-6Al-4V</u>	Hole spacing (in.): <u>1-1/8</u>
Material gage (in.): <u>0.375</u>	Nominal hole size (in.): <u>3/8</u>
Size (L x W)(in.): <u>15 x 1.5</u>	Edge margin: <u>0.75 in.</u>
Number of holes: <u>12</u>	

### Coldwork Information

Coldwork process: <u>Sleeve</u>
Mandrel taper (in./in.): <u>0.045</u>
Mandrel diameter (in.): <u>0.3537</u>
Expansion (in.): <u>0.018</u>

## RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.0015</u>
Edge bulge between holes, average (in.):	<u>0.0010</u>
<sup>a</sup> Bow after coldwork (in.):	<u>+0.035</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>None</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>0.001</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.016 in 12.375</u>
Specimen growth after ream (in.):	<u>0.018 in 12.375</u>
Specimen growth after countersink (in.):	<u>0.0175 in 12.375</u>

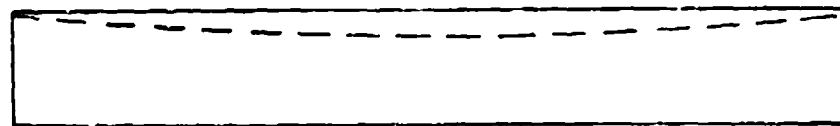
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
(-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

# PHASE I-TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 2T

DATE: 1/8/73

## TEST CONDITIONS

### Specimen Description

Material: Ti-6Al-4V  
 Material gage (in.): 0.375  
 Size (L x W)(in.): 15 x 1.5  
 Number of holes: 9

Hole spacing (in.): 1.5  
 Nominal hole size (in.): 3/8  
 Edge margin: 0.75 in.

### Coldwork Information

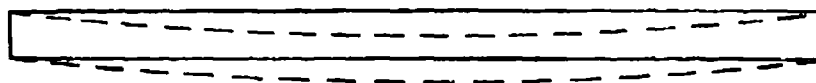
Coldwork process: Sleeve  
 Mandrel taper (in./in.): 0.045  
 Mandrel diameter (in.): 0.3537  
 Expansion (in.): 0.018

## RESULTING DATA

Edge bulge at holes, average (in.): 0.0010  
 Edge bulge between holes, average (in.): 0.0005  
<sup>a</sup>Bow after coldwork (in.): +0.017  
<sup>a</sup>Bow after ream and countersink (in.): -0.005  
<sup>b</sup>Edge distortion after coldwork (in.): 0.002  
<sup>c</sup>Specimen growth after coldwork (in.): 0.016 in 12  
 Specimen growth after ream (in.): 0.017 in 12  
 Specimen growth after countersink (in.): 0.017 in 12

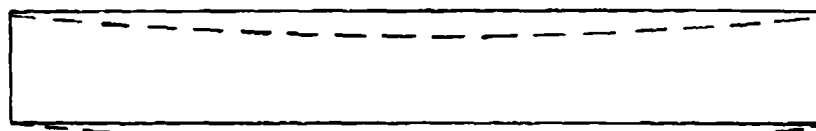
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance.

# PHASE I- TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 3T

DATE: 1/8/73

## TEST CONDITIONS

### Specimen Description

Material: Ti-6Al-4V  
 Material gage (in.): 0.375  
 Size (L x W)(in.): 15 x 1-1/8  
 Number of holes: 12

Hole spacing (in.): 1-1/8  
 Nominal hole size (in.): 3/8  
 Edge margin: 0.563 in.

### Coldwork Information

Coldwork process: Sleeve  
 Mandrel taper (in./in.): 0.045  
 Mandrel diameter (in.): 0.3537  
 Expansion (in.): 0.018

## RESULTING DATA

Edge bulge at holes, average (in.): 0.0032  
 Edge bulge between holes, average (in.): 0.0010  
<sup>a</sup>Bow after coldwork (in.): +0.042  
<sup>a</sup>Bow after ream and countersink (in.): +0.016  
<sup>b</sup>Edge distortion after coldwork (in.): 0.001  
<sup>c</sup>Specimen growth after coldwork (in.): 0.0145 in 12.375  
 Specimen growth after ream (in.): 0.0130 in 12.375  
 Specimen growth after countersink (in.): 0.0130 in 12.375

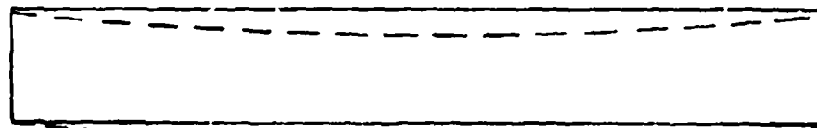
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

# PHASE I--TASK 4A--EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 4T DATE: 1/8/73

## TEST CONDITIONS

### Specimen Description

Material: <u>Ti-6Al-4V</u>	Hole spacing (in.): <u>1.5</u>
Material gage (in.): <u>0.375</u>	Nominal hole size (in.): <u>3/8</u>
Size (L x W)(in.): <u>15 x 1-1/8</u>	Edge margin: <u>0.563 in.</u>
Number of holes: <u>9</u>	

### Coldwork Information

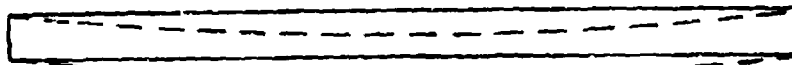
Coldwork process: <u>Sleeve</u>
Mandrel taper (in./in.): <u>0.045</u>
Mandrel diameter (in.): <u>0.3537</u>
Expansion (in.): <u>0.018</u>

## RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.0024</u>
Edge bulge between holes, average (in.):	<u>0.0005</u>
<sup>a</sup> Bow after coldwork (in.):	<u>+0.055</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>+0.028</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>0.003</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.0145 in 12</u>
Specimen growth after ream (in.):	<u>0.0160 in 12</u>
Specimen growth after countersink (in.):	<u>0.0155 in 12</u>

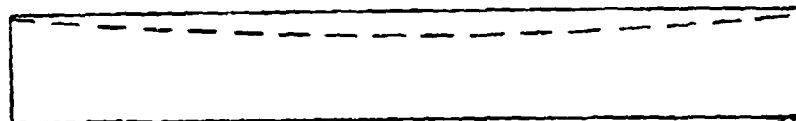
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
(-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

# PHASE I-TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 7T

DATE: 1/8/73

## TEST CONDITIONS

### Specimen Description

Material: Ti-6Al-4V  
 Material gage (in.): 0.75  
 Size (L x W)(in.): 15 x 2-1/4  
 Number of holes: 6

Hole spacing (in.): 2-1/4  
 Nominal hole size (in.): 3/4  
 Edge margin: 1.125 in.

### Coldwork Information

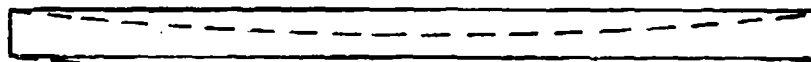
Coldwork process: Sleeve  
 Mandrel taper (in./in.): 0.045  
 Mandrel diameter (in.): 0.714  
 Expansion (in.): 0.029

## RESULTING DATA

Edge bulge at holes, average (in.): 0.003  
 Edge bulge between holes, average (in.): 0.001  
<sup>a</sup>Bow after coldwork (in.): +0.003  
<sup>a</sup>Bow after ream and countersink (in.): -0.030  
<sup>b</sup>Edge distortion after coldwork (in.): None  
<sup>c</sup>Specimen growth after coldwork (in.): 0.0110 in 11.25  
 Specimen growth after ream (in.): 0.0120 in 11.25  
 Specimen growth after countersink (in.): 0.0115 in 11.25

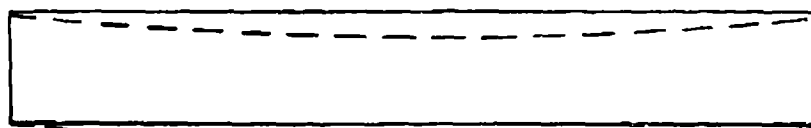
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance.

# PHASE I-TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 8T DATE: 1/8/73

## TEST CONDITIONS

### Specimen Description

Material: <u>Ti-6Al-4V</u>	Hole spacing (in.): <u>3</u>
Material gage (in.): <u>0.75</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W) (in.): <u>15 x 2-1/4</u>	Edge margin: <u>1-1/8 in.</u>
Number of holes: <u>4</u>	

### Coldwork Information

Coldwork process: Sleeve  
Mandrel taper (in./in.): 0.045  
Mandrel diameter (in.): 0.714  
Expansion (in.): 0.029

## RESULTING DATA

Edge bulge at holes, average (in.): 0.003  
Edge bulge between holes, average (in.): 0.0005  
<sup>a</sup>Bow after coldwork (in.): +0.017  
<sup>a</sup>Bow after ream and countersink (in.): +0.011  
<sup>b</sup>Edge distortion after coldwork (in.): None  
<sup>c</sup>Specimen growth after coldwork (in.): 0.006 in 9  
Specimen growth after ream (in.): 0.006 in 9  
Specimen growth after countersink (in.): 0.006 in 9

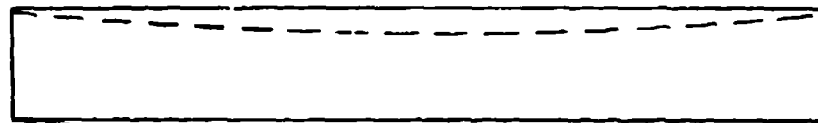
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
(-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance.

# PHASE I-TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 9T DATE: 1/8/73

## TEST CONDITIONS

### Specimen Description

Material: <u>Ti-6Al-4V</u>	Hole spacing (in.): <u>2-1/4</u>
Material gage (in.): <u>0.75</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W) (in.): <u>15 x 3</u>	Edge margin: <u>1.50 in.</u>
Number of holes: <u>6</u>	

### Coldwork Information

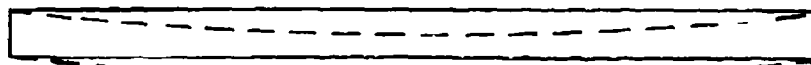
Coldwork process: Sleeve  
Mandrel taper (in./in.): 0.045  
Mandrel diameter (in.): 0.714  
Expansion (in.): 0.029

## RESULTING DATA

Edge bulge at holes, average (in.): 0.0025  
Edge bulge between holes, average (in.): 0.0010  
<sup>a</sup>Bow after coldwork (in.): +0.012  
<sup>a</sup>Bow after ream and countersink (in.): +0.003  
<sup>b</sup>Edge distortion after coldwork (in.): None  
<sup>c</sup>Specimen growth after coldwork (in.): 0.0085 in 11.25  
Specimen growth after ream (in.): 0.0075 in 11.25  
Specimen growth after countersink (in.): 0.0075 in 11.25

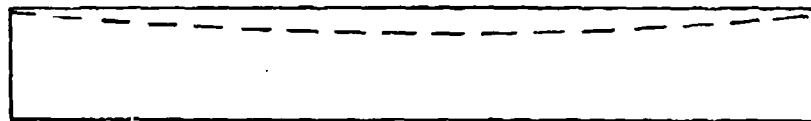
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) indicates bow as shown in sketch  
(-) indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

# PHASE I - TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 10T DATE: 1/8/73

## TEST CONDITIONS

### Specimen Description

Material: <u>Ti-6Al-4V</u>	Hole spacing (in.): <u>3</u>
Material gage (in.): <u>0.75</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W)(in.): <u>15 x 3</u>	Edge margin: <u>1-1/2 in.</u>
Number of holes: <u>4</u>	

### Coldwork Information

Coldwork process: <u>Sleeve</u>
Mandrel taper (in./in.): <u>0.045</u>
Mandrel diameter (in.): <u>0.714</u>
Expansion (in.): <u>0.029</u>

## RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.0025</u>
Edge bulge between holes, average (in.):	<u>0.0010</u>
<sup>a</sup> Bow after coldwork (in.):	<u>None</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>-0.010</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>None</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.0030 in 9</u>
Specimen growth after ream (in.):	<u>0.0020 in 9</u>
Specimen growth after countersink (in.):	<u>0.0020 in 9</u>

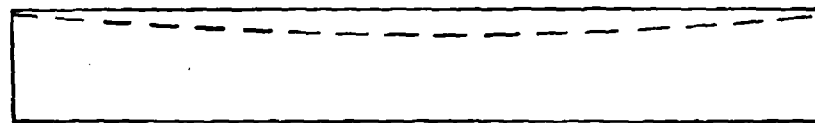
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
(-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

# PHASE I-TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 1S

DATE: 6/1/73

## TEST CONDITIONS

### Specimen Description

Material: 300 M steel  
 Material gage (in.): 0.375  
 Size (L x W)(in.): 15 x 1.125  
 Number of holes: 9

Hole spacing (in.): 1.50  
 Nominal hole size (in.): 3/8  
 Edge margin: 9/16 in.

### Coldwork Information

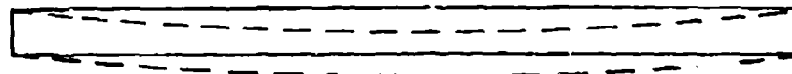
Coldwork process: Push, no sleeve  
 Mandrel taper (in./in.): 0.045  
 Mandrel diameter (in.): 0.358  
 Expansion (in.): 0.023

## RESULTING DATA

Edge bulge at holes, average (in.): 0.0031  
 Edge bulge between holes, average (in.): 0.0007  
<sup>a</sup>Bow after coldwork (in.): 0.103  
<sup>a</sup>Bow after ream and countersink (in.): 0.101  
<sup>b</sup>Edge distortion after coldwork (in.): 0.013  
<sup>c</sup>Specimen growth after coldwork (in.): 0.032 in 15  
 Specimen growth after ream (in.): 0.032 in 15 (no change)  
 Specimen growth after countersink (in.): 0.032 in 15 (no change)

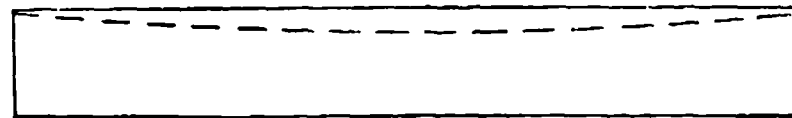
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance.

# PHASE I-TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 2S DATE: 6/14/73

## TEST CONDITIONS

### Specimen Description

Material: <u>300 M steel</u>	Hole spacing (in.): <u>1.125</u>
Material gage (in.): <u>3/8</u>	Nominal hole size (in.): <u>3/8</u>
Size (L x W)(in.): <u>15 x 1.125</u>	Edge margin: <u>9/16 in.</u>
Number of holes: <u>12</u>	

### Coldwork Information

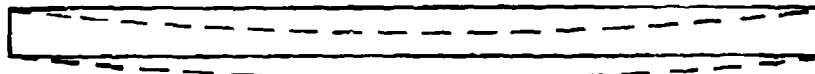
Coldwork process: Push, no sleeve  
Mandrel taper (in./in.): 0.045  
Mandrel diameter (in.): 0.3580  
Expansion (in.): 0.0230

## RESULTING DATA

Edge bulge at holes, average (in.): 0.0030  
Edge bulge between holes, average (in.): 0.0010  
<sup>a</sup>Bow after coldwork (in.): +0.102  
<sup>a</sup>Bow after ream and countersink (in.): +0.102  
<sup>b</sup>Edge distortion after coldwork (in.): None  
<sup>c</sup>Specimen growth after coldwork (in.): 0.030 in 15  
Specimen growth after ream (in.): 0.030 in 15 (no change)  
Specimen growth after countersink (in.): 0.030 in 15 (no change)

<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
(-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance.

# PHASE I-TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 3S

DATE: 6/14/73

## TEST CONDITIONS

### Specimen Description

Material: 300 M steel  
 Material gage (in.): 3/8  
 Size (L x W) (in.): 15 x 1.50  
 Number of holes: 12

Hole spacing (in.): 1.125  
 Nominal hole size (in.): 3/8  
 Edge margin: 0.750 in.

### Coldwork Information

Coldwork process: Push, no sleeve  
 Mandrel taper (in./in.): 0.045  
 Mandrel diameter (in.): 0.358  
 Expansion (in.): 0.023

## RESULTING DATA

Edge bulge at holes, average (in.): 0.0017  
 Edge bulge between holes, average (in.): 0.0012  
<sup>a</sup>Bow after coldwork (in.): 0.0525  
<sup>a</sup>Bow after ream and countersink (in.): 0.0520  
<sup>b</sup>Edge distortion after coldwork (in.): None  
<sup>c</sup>Specimen growth after coldwork (in.): 0.025 in 15  
 Specimen growth after ream (in.): 0.025 in 15 (no change)  
 Specimen growth after countersink (in.): 0.025 in 15 (no change)

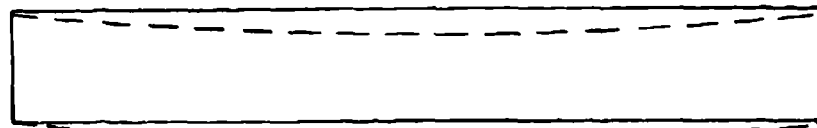
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow.

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance.

# PHASE I: TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 4S DATE: 5/30/73

## TEST CONDITIONS

### Specimen Description

Material: <u>300 M steel</u>	Hole spacing (in.): <u>1.50</u>
Material gage (in.): <u>0.375</u>	Nominal hole size (in.): <u>0.375</u>
Size (L x W)(in.): <u>15 x 1.50</u>	Edge margin: <u>0.75 in.</u>
Number of holes: <u>9</u>	

### Coldwork Information

Coldwork process: Push, no sleeve

Mandrel taper (in./in.): 0.045

Mandrel diameter (in.): 0.358

Expansion (in.): 0.023

## RESULTING DATA

Edge bulge at holes, average (in.): 0.0015

Edge bulge between holes, average (in.): 0.0007

<sup>a</sup>Bow after coldwork (in.): 0.064

<sup>a</sup>Bow after ream and countersink (in.): 0.060

<sup>b</sup>Edge distortion after coldwork (in.): 0.005

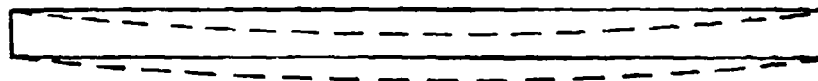
<sup>c</sup>Specimen growth after coldwork (in.): 0.018 in 15

Specimen growth after ream (in.): 0.018 in 15 (no change)

Specimen growth after countersink (in.): 0.018 in 15 (no change)

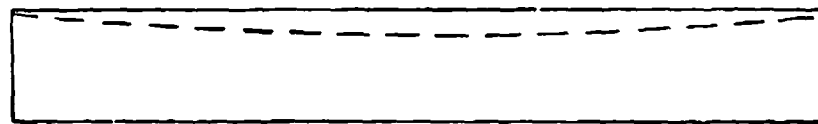
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
(-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

# PHASE I-TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 7S DATE: 7/5/73

## TEST CONDITIONS

### Specimen Description

Material: <u>300 M steel</u>	Hole spacing (in.): <u>2.25</u>
Material gage (in.): <u>0.75</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W)(in.): <u>15 x 3</u>	Edge margin: <u>1-1/2 in.</u>
Number of holes: <u>6</u>	

### Coldwork Information

Coldwork process: Push, no sleeve

Mandrel taper (in./in.): 0.045

Mandrel diameter (in.): 0.7225

Expansion (in.): 0.030

## RESULTING DATA

Edge bulge at holes, average (in.): 0.0025

Edge bulge between holes, average (in.): 0.0007

<sup>a</sup>Bow after coldwork (in.): +0.013

<sup>a</sup>Bow after ream and countersink (in.): +0.013

<sup>b</sup>Edge distortion after coldwork (in.): None

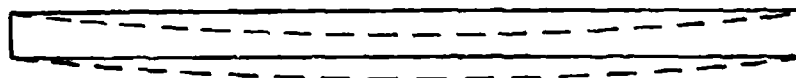
<sup>c</sup>Specimen growth after coldwork (in.): 0.014 in 15

Specimen growth after ream (in.): No change

Specimen growth after countersink (in.): No change

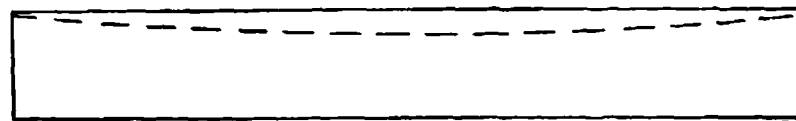
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
(-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance.

# PHASE I--TASK 4A--EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 8S

DATE: 7/5/73

## TEST CONDITIONS

### Specimen Description

Material: 300 M steel

Material gage (in.): 0.75

Size (L x W)(in.): 15 x 3

Number of holes: 4

Hole spacing (in.): 3

Nominal hole size (in.): 3/4

Edge margin: 1-1/2 in.

### Coldwork Information

Coldwork process: Push, no sleeve

Mandrel taper (in./in.): 0.045

Mandrel diameter (in.): 0.7225

Expansion (in.): 0.030

## RESULTING DATA

Edge bulge at holes, average (in.): 0.0025

Edge bulge between holes, average (in.): None

<sup>a</sup>Bow after coldwork (in.): +0.010

<sup>a</sup>Bow after ream and countersink (in.): +0.010

<sup>b</sup>Edge distortion after coldwork (in.): None

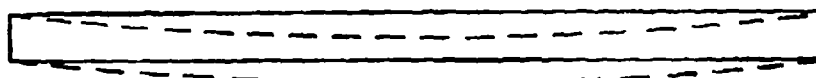
<sup>c</sup>Specimen growth after coldwork (in.): 0.010 in 15

Specimen growth after ream (in.): No change

Specimen growth after countersink (in.): No change

<sup>a</sup>Bow direction

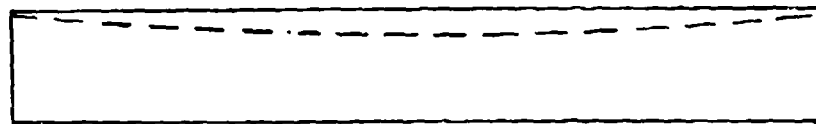
↓ Direction of coldwork



(+) Indicates bow as shown in sketch

(-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

# PHASE I-TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 9 S DATE: 7/5/73

## TEST CONDITIONS

### Specimen Description

Material: <u>300 M steel</u>	Hole spacing (in.): <u>2.25</u>
Material gage (in.): <u>0.75</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W)(in.): <u>15 x 2.25</u>	Edge margin: <u>1-1.5 in.</u>
Number of holes: <u>6</u>	

### Coldwork Information

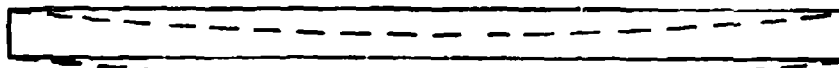
Coldwork process: Push, no sleeve  
Mandrel taper (in./in.): 0.045  
Mandrel diameter (in.): 0.7225  
Expansion (in.): 0.030

## RESULTING DATA

Edge bulge at holes, average (in.): 0.0035  
Edge bulge between holes, average (in.): 0.0015  
<sup>a</sup>Bow after coldwork (in.): 0.030  
<sup>a</sup>Bow after ream and countersink (in.): 0.030  
<sup>b</sup>Edge distortion after coldwork (in.): 0.005  
<sup>c</sup>Specimen growth after coldwork (in.): 0.013 in 15  
Specimen growth after ream (in.): No change  
Specimen growth after countersink (in.): No change

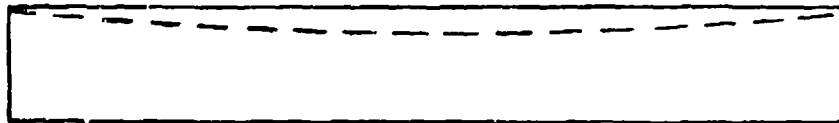
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
(-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

# PHASE I-TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 10 S DATE: 7/5/73

## TEST CONDITIONS

### Specimen Description

Material: <u>300 M steel</u>	Hole spacing (in.): <u>3.00</u>
Material gage (in.): <u>0.75</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W) (in.): <u>15 x 2.25</u>	Edge margin: <u>1-1/8 in.</u>
Number of holes: <u>4</u>	

### Coldwork Information

Coldwork process: Push, no sleeve

Mandrel taper (in. in.): 0.045

Mandrel diameter (in.): 0.7225

Expansion (in.): 0.035 & 0.046

## RESULTING DATA

Edge bulge at holes, average (in.): 0.004 (.035 interf.) & .0055 (.046 interf.)

Edge bulge between holes, average (in.): None (both cases)

<sup>a</sup>Bow after coldwork (in.): 0.026

<sup>a</sup>Bow after ream and countersink (in.): 0.026

<sup>b</sup>Edge distortion after coldwork (in.): None

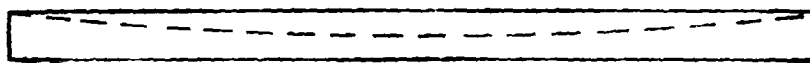
<sup>c</sup>Specimen growth after coldwork (in.): 0.011 in 15

Specimen growth after ream (in.): No change

Specimen growth after countersink (in.): No change

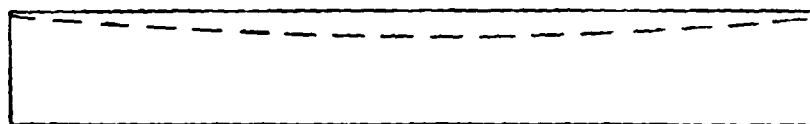
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
(-) Indicates bow in opposite direction


<sup>b</sup>Edge distortion



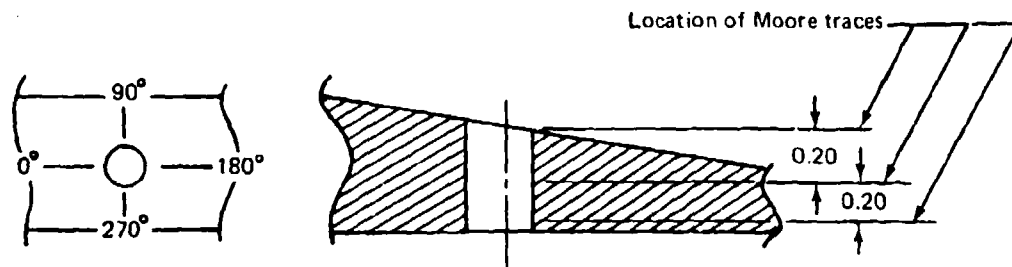
Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

# PHASE I-TASK 48-MATERIAL TAPER EFFECT

Material	Taper (deg)	Centerline shift (in.)	Direction of shift
2024-T851 (Al)	2	0.0035	<p>Top of hole moved as illustrated in all cases</p> <p>→</p> <p>Direction of shift</p> 
2024-T851 (Al)	4	0.0035	
Ti-6Al-4V	2	0.002	
Ti-6Al-4V	4	0.003	

PHASE I - TASK 4B - SPECIMEN S5, 300M STEEL 2° TAPER

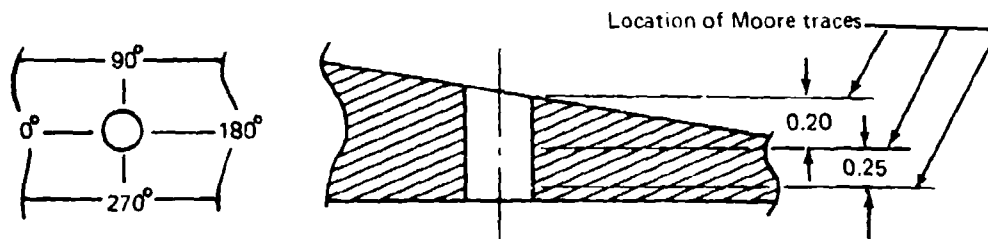


Before coldworking: Center of top of hole, 0.0025 in. toward 180° and 0.0015 in. toward 90°

After coldworking: Center of top of hole, 0.0010 in. toward 180° and 0.0025 in. toward 90°

Conclusion: Center of top of hole moved 0.0008 in. toward 180° (down slope)

SPECIMEN S6, 300M STEEL, 4° TAPER

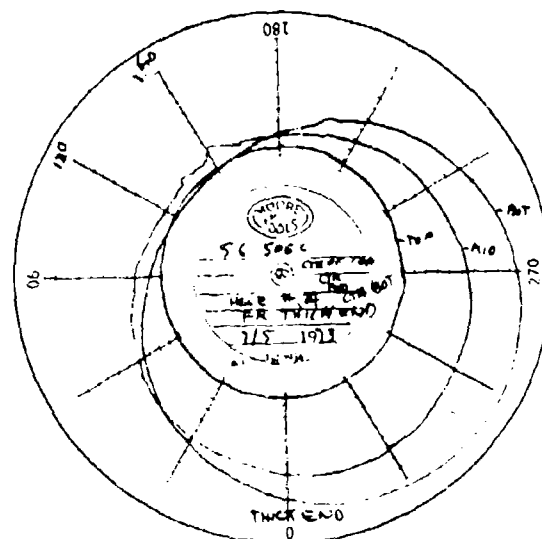
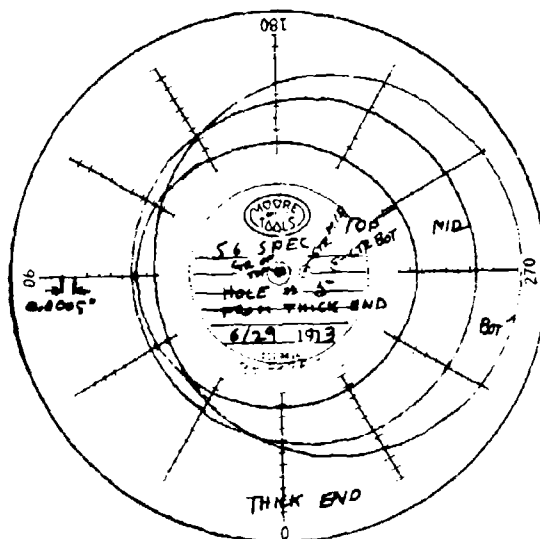
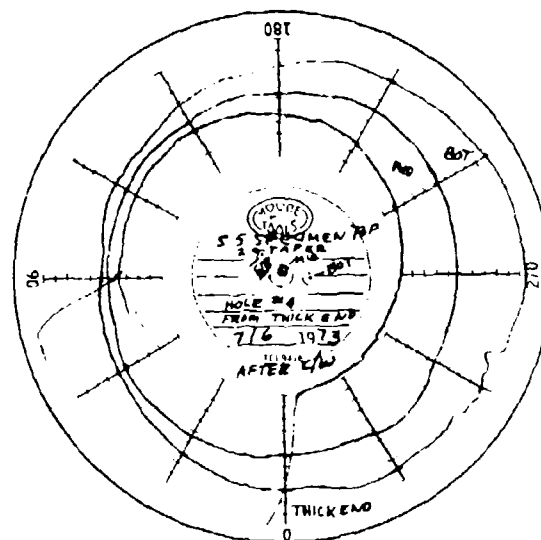
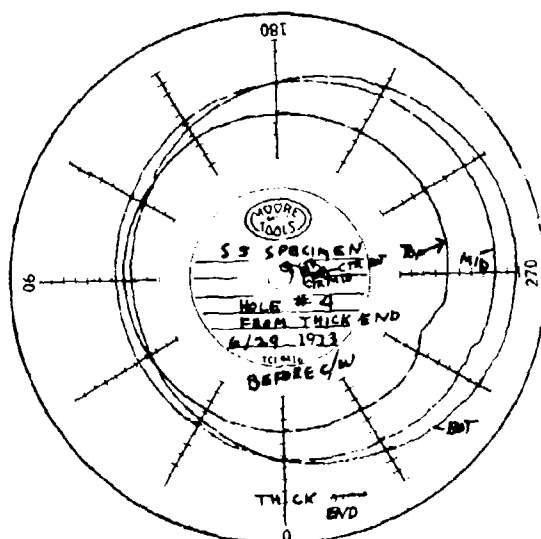


Before coldworking: Center of top of hole 0.0025 in. toward 90° from center of bottom of hole

After coldworking: Center of top of hole 0.0025 in. toward 150° from center of bottom of hole

Conclusion: Center of top of hole moved approximately 0.0017 in. toward 180° (down slope)

PHASE I - TASK 4B - MOORE TRACE DATA FOR 300M STEEL; CENTERLINE SHIFT AS A  
RESULT OF SURFACE TAPER



PHASE I - TASK 4C - LUBRICANT VARIATION

DATE: 1/23/73

MANDREL TAPER (in./in.): 0.045

COLDWORK PROCESS: Sleeve

MATERIAL: 2024-T851(AI)

MATERIAL THICKNESS (in.): 0.375

NOMINAL HOLE SIZE (in.): 3/8

Hole no.	Maximum expansion (in.)	Sleeve lubricant	Pull force (lb)	Remarks
A1	0.0130	Fel Pro 300	945	Standard sleeve presently used in production
A2	0.0130	Fel Pro 300	1000	
A3	0.0130	Fel Pro 300	1005	
A4	0.0130	Fel Pro 300	965	
A5	0.0130	Fel Pro 300	975	
A6	0.0130	LLC 36 air dried	1500	Loud snapping (chatter) occurred throughout test; pickup on mandrel.
A7	0.0130	LLC 36 air dried	1500	
A8	0.0130	LLC 36 air dried	1535	
B1	0.0130	LLC 36 air dried	1415	
B2	0.0130	LLC 36 air dried	1405	
B3	0.0130	LLC 36 baked	1490	Pickup from air dried LLC 36 removed from mandrel.
B4	0.0130	LLC 36 baked	1420	
B5	0.0130	LLC 36 baked	1380	
B6	0.0130	LLC 36 baked	1510	
B7	0.0130	LLC 36 baked	1505	
B8	0.0130	Moly Kote-G paste	1560	Sleeve lubed inside and mandrel lubed after insertion in plate.
C1	0.0130	Moly Kote-G paste	1470	
C2	0.0130	Moly Kote-G paste	1420	
C3	0.0130	Moly Kote-G paste	1410	
C4	0.0130	Moly Kote-G paste	1400	

# PHASE I-TASK 4C-SLEEVE LUBRICANT TESTS

(Boeing and Program Data)

Sleeve lubricant:			Mandrel wipe	Hole diameter (in.)	Material thickness (in.)	Hole expansion	Material	Average force (lb)					
								0.045-in. taper	0.034-in. taper	0.030-in. taper	0.025-in. taper	0.020-in. taper	0.015-in. taper
Basic	+	Additive											
Fel Pro 300 (properly mixed)		-	Dry	3/8	3/8	0.013	2024-T851	965		1,250			1,400
LLC 36 air dried		-						1,470					
LLC 36 baked		-						1,460					
Moly Kote-G paste		-	Moly Kote-G paste					1,450					
Fel Pro 300 (properly mixed)		-	Dry	3/4	1-1/8	0.025		6,500		7,500	12,000		
		-			2		7075-T651		8,880		9,870	10,830	15,440
		-	Ethyl alcohol						10,600		12,660	11,800	15,430
		Docosanol alcohol	Dry										21,400
		Johnson 150 wax draw											15,400
			Ethyl alcohol										17,200
		Eicosanol alcohol											22,200
			Dry										22,700
		Stearyl alcohol											17,500
			Ethyl alcohol										19,200
		Cetyl alcohol (hot coat)											17,300
			Dry										18,000

[illegible]

PHASE I - TASK 4C-SLEEVE LUBRICANT TESTS  
(Boeing and Program Data)

Sleeve lubricant		Mandrel wipe	Hole diameter (in.)	Material thickness (in.)	Hole expansion	Material	Average force (lb)					
Basic	Additive						0.045-in. taper	0.034-in. taper	0.030-in. taper	0.025-in. taper	0.020-in. taper	0.015-in. taper
Fel Pro 300 (improperly mixed)	Coconut oil	Ethyl alcohol	3/4	2	0.025	7075-T651						Mandrel seized
	Johnson 700 wax draw											20,460
		Dry										20,400
	Johnson 122 wax cut	Ethyl alcohol										Mandrel seized
	LPS-1	Dry										Seized
	LPS-2											Seized
	LPS-3										19,600	Seized
	Castor wax										18,400	24,100
	Carnauba wax											Seized
Paraffin	-											16,050
Cetyl alcohol (paste coat)	-											27,500
	-	Ethyl alcohol										12,040
Fel Pro 300 (properly mixed)	Heat dried before use	Dry										

PHASE I—TASK 4D—SLEEVE GEOMETRY

DATE: 1/30/73

MATERIAL: 2024 T851 (Al) MANDREL TAPER (IN./IN.): 0.045

MATERIAL THICKNESS (IN.): 0.75 MAXIMUM EXPANSION (IN.): 0.019

Hole no.	Sleeve type	Retained expansion (in.)	Pull force (lb)	Remarks
1	Standard	0.0105	2280	
2	Standard	0.0110	1980	
3	30° scarf edge	0.0100	2000	(a)
4	30° scarf edge	0.0105	2030	
5	Helical wound	0.0105	2160	Helically wound sleeves are easier to remove than standard or scarf edge sleeves. Profile shows less upset at exit. There is less diametrical difference between top, middle, and exit of hole.
6	Helical wound	0.0105	2180	
7	Helical wound	0.0115	2120	
8	Helical wound	0.0110	2125	
9	Helical wound	0.0105	1950	

<sup>a</sup> Additional tests were conducted in aluminum (2024-T851) and Ti-6Al-4V comparing removal characteristics of 30° scarf split sleeves with standard sleeves. These tests showed that there was no appreciable difference between the two. Close examination of the scarf indicated that it was not uniform.

PHASE I-TASK 4E-DIAMETER CREEP

DATE: 2/6/73

MAXIMUM EXPANSION (IN.): 0.018-0.020

NOMINAL HOLE SIZE (IN.): 3/8

MANDREL TAPER (IN./IN.): 0.045

PROCESS : REAM, COLDWORK, REAM

MATERIAL THICKNESS (IN.): 0.075

Material tested	Hole size (in.)		
	Immediately after ream	One hour after ream	24 hours after ream
2024-T851 (Al)	0.3753/0.3754	0.3752/0.3753	0.3752/0.3753
Ti-6Al-4V	0.3753/0.3754	0.3752/0.3753	0.3752/0.3753

PHASE I--TASK 4F--MANDREL FINISH VARIATION

DATE: 2/7/73

MATERIAL: 2024-T851 (AI)

MATERIAL THICKNESS (IN.): 0.75

NOMINAL HOLE SIZE (IN.): 3/8

MAXIMUM EXPANSION (IN.): 0.018-0.020

MANDREL TAPER (IN./IN.): 0.045

COLDWORK PROCESS: Sleeve

Hole no.	Mandrel finish	Force (lb)
1	None	2800
2	None	2840
3	None	2800
4	None	2600
5	Vapor blast + Fel Pro 300	3000
6	↓	2580
7		2400
8		2500
9		2480
10		2470
11		2780
12		2540

# PHASE I-TASK 4F-MANDREL FINISH VARIATION

DATE: 2/7/73

MATERIAL: Ti-6Al-4V

MATERIAL THICKNESS (IN.) 0.75

NOMINAL HOLE SIZE (IN.) 3/8

MAXIMUM EXPANSION (IN.) 0.018-0.020

MANDREL TAPER (IN./IN.) 0.045

COLDWORK PROCESS: Sleeve

Hole no.	Mandrel finish	Force (lb)
1	None	3740
2	None	3860
3	None	3700
4	Vapor blast + Fel Pro 300	3560
5	↓	3470
6		3600
7		3680
8		3650

PHASE I-TASK 5-MULTIMATERIAL STACK PROCESS DATA

SPECIMEN NUMBER: IV TEST NUMBER: 1 DATE: 12/13/72

MATERIAL COMBINATION: 1. 2024-T851 2. 6Al-4V-Ti 3. 2024-T851 MANDREL TYPE: ST 5300-CBM-12.0-N

MATERIAL GAGE (IN.) 1. 0.250 2. 0.290 3. 0.250 MANDREL TAPER (IN./IN.): 0.045

NOMINAL HOLE SIZE (IN.) 3/8 MANDREL MAX DIA (IN.): 0.3537

SLEEVE THICKNESS (IN.): 0.010

LUBRICANT (SLEEVE): Fel Pro 300 (on sleeve)

Hole no.	Hole diameter (in.)			Pull force (lb)	Actual coldwork diameter expansion (in.)	Retained diameter expansion in aluminum (in.)	Retained diameter expansion in titanium (in.)	Remarks
	Before coldwork		After coldwork					
	Ti	Al	Ti	Al				
C-7	0.3555	0.3550	0.3660	0.3675	0.019	0.0125	0.0105	Sleeves fairly easy to remove 3 sleeves required use of screw driver for removal-rest pulled out with pliers.
C-8	0.3555	0.3555	0.3665	0.3675	0.019	0.0120	0.0110	
D-1	0.3550	0.3545	0.3660	0.3675	0.019	0.0130	0.0110	
D-2	0.3555	0.3545	0.3665	0.3675	0.019	0.0130	0.0110	
D-3	0.3555	0.3545	0.3660	0.3675	0.019	0.0130	0.0105	
D-4	0.3555	0.3545	0.3660	0.3680	0.019	0.0135	0.0105	
D-5	0.3550	0.3545	0.3660	0.3675	0.019	0.0130	0.0110	
D-6	0.3550	0.3545	0.3660	0.3680	0.019	0.0135	0.0110	
D-7	0.3550	0.3545	0.3660	0.3680	0.019	0.0135	0.0110	
D-8	0.3550	0.3545	0.3660	0.3675	0.019	0.0130	0.0110	

PHASE I - TASK 5 - MULTIMATERIAL STACK PROCESS DATA

SPECIMEN NUMBER: IV TEST NUMBER: 2 DATE: 12/13/72

MATERIAL COMBINATION: 1. 2024-T851 2. 6Al-4V-Ti 3. 2024-T851 MANDREL TYPE: ST 5300-CBM-12-O-N

MATERIAL GAGE (IN.) 1. 0.250 2. 0.290 3. 0.250 MANDREL TAPER (IN./IN.): 0.045

NOMINAL HOLE SIZE (IN.) 3/8 MANDREL MAX DIA (IN.): 0.3537

SLEEVE THICKNESS (IN.): 0.010

LUBRICANT (SLEEVE): Fel Pro 300 (on sleeve)

Hole no.	Hole diameter (in.)				Pull force (lb)	Actual coldwork diameter expansion (in.)	Retained diameter expansion in aluminum (in.)	Retained diameter expansion in titanium (in.)	Remarks
	Before coldwork		After coldwork						
	Ti	Al	Ti	Al					
A1	0.3595	0.3600	0.3560	0.3680	1795	0.014	0.0065	0.0080	Sleeves easy to remove with pliers—most free to slide in hole.
A2	0.3595	0.3600	0.3565	0.3680	1595	0.014	0.0070	0.0080	
A3	0.3595	0.3600	0.3565	0.3680	1495	0.014	0.0070	0.0080	
A4	0.3595	0.3600	0.3565	0.3680	1480	0.014	0.0065	0.0080	
A5	0.3595	0.3600	0.3565	0.3680	1615	0.014	0.0070	0.0080	
A6	0.3595	0.3600	0.3570	0.3680	1680	0.014	0.0075	0.0080	
A7	0.3595	0.3600	0.3560	0.3690	1650	0.014	0.0065	0.0090	
A8	0.3595	0.3600	0.3560	0.3680	1780	0.014	0.0065	0.0080	
B1	0.3595	0.3600	0.3570	0.3680	1765	0.014	0.0075	0.0080	
B2	0.3595	0.3600	0.3560	0.3685	2060	0.014	0.0065	0.0085	

PHASE I-TASK 5-MULTIMATERIAL STACK PROCESS DATA

SPECIMEN NUMBER: IV TEST NUMBER: 3 DATE: 12/13/72

MATERIAL COMBINATION: 1. 2024-T851 2. 6Al-4V-Ti 3. 2024-T851 MANDREL TYPE: ST 5300-CBM-12-0-N

MATERIAL GAGE (IN.) 1. 0.250 2. 0.290 3. 0.250 MANDREL TAPER (IN./IN.): 0.045

NOMINAL HOLE SIZE (IN.) 3/8 MANDREL MAX DIA (IN.): 0.3537

SLEEVE THICKNESS (IN.): 0.010

LUBRICANT (SLEEVE): Fel Pro 300 (on sleeve)

Hole no.	Hole diameter (in.)				Pull force (lb)	Actual coldwork diameter expansion (in.)	Retained diameter expansion in aluminum (in.)	Retained diameter expansion in titanium (in.)	Remarks
	Before coldwork		After coldwork						
	Ti	Al	Ti	Al					
F1	0.3655	0.3655	0.3680	0.3680	1565	0.008	0.0035	0.0025	Sleeves easy to remove—free to pull out with fingers.
F2	0.3655	0.3655	0.3685	0.3695	1440	0.008	0.0040	0.0030	
F3	0.3655	0.3655	0.3685	0.3695	1350	0.008	0.0040	0.0030	
F4	0.3655	0.3655	0.3685	0.3690	1365	0.008	0.0035	0.0030	
F5	0.3655	0.3655	0.3680	0.3690	1350	0.008	0.0035	0.0025	
F6	0.3655	0.3655	0.3680	0.3690	1360	0.008	0.0035	0.0025	
G1	0.3655	0.3655	0.3680	0.3690	1350	0.008	0.0035	0.0025	
G2	0.3655	0.3655	0.3680	0.3690	1350	0.008	0.0035	0.0025	
G3	0.3655	0.3655	0.3680	0.3690	1360	0.008	0.0035	0.0025	
G4	0.3655	0.3655	0.3685	0.3695	1355	0.008	0.0040	0.0030	

# PHASE I - TASK 5 - MULTIMATERIAL STACK PROCESS DATA

SPECIMEN NUMBER: 2V TEST NUMBER: 4 DATE: 12/13/72

MATERIAL COMBINATION: 1. 6Al-4V-Ti 2. 2024-T851 3. 6Al-4V-Ti MANDREL TYPE: ST 53100-C8M-12-0-N

MATERIAL GAGE (IN.) 1. 0.285 2. 1.00 3. 0.285 MANDREL TAPER (IN./IN.): 0.045

NOMINAL HOLE SIZE (IN.) 3/8 MANDREL MAX DIA (IN.): 0.3537

SLEEVE THICKNESS (IN.): 0.010

LUBRICANT (SLEEVE): Fe/Pro 300

Hole no.	Hole diameter (in.)				Pull force (lb)	Actual coldwork diameter expansion (in.)	Retained diameter expansion in aluminum (in.)	Retained diameter expansion in titanium (in.)	Remarks
	Before coldwork		After coldwork						
	Ti	Al	Ti	Al					
C7	0.3550	0.3550	0.3660	0.3685	3640	0.019	0.0135	0.0110	1. Sleeves fairly easy to remove—4 sleeves required use of screwdriver for removal—rest pulled out with pliers.  2. Sleeve thinout accounts for much of the difference in retained expansion.
C8	0.3550	0.3550	0.3665	0.3685	3520	0.019	0.0135	0.0115	
D1	0.3550	0.3550	0.3660	0.3680	3520	0.019	0.0130	0.0110	
D2	0.3550	0.3550	0.3660	0.3685	3560	0.019	0.0135	0.0110	
D3	0.3550	0.3550	0.3665	0.3680	3500	0.019	0.0130	0.0115	
D4	0.3550	0.3550	0.3665	0.3680	3380	0.019	0.0130	0.0115	
D5	0.3550	0.3550	0.3665	0.3685	3320	0.019	0.0135	0.0115	
D6	0.3550	0.3550	0.3660	0.3685	3320	0.019	0.0135	0.0110	
D7	0.3550	0.3550	0.3660	0.3685	3420	0.019	0.0135	0.0110	
D8	0.3550	0.3550	0.3660	0.3685	3560	0.019	0.0135	0.0110	

# PHASE I—TASK 5—MULTIMATERIAL STACK PROCESS DATA

SPECIMEN NUMBER: 2V TEST NUMBER: 5 DATE: 12/13/72

MATERIAL COMBINATION: 1. 6Al-4V-Ti 2. 2024-T851 3. 6Al-4V-Ti MANDREL TYPE: ST 5300-CBM-12-0-N

MATERIAL GAGE (IN.) 1. 0.285 2. 1.00 3. 0.285 MANDREL TAPER (IN./IN.): 0.045

NOMINAL HOLE SIZE (IN.) 3/8 MANDREL MAX DIA (IN.): 0.3537

SLEEVE THICKNESS (IN.): 0.010

LUBRICANT (SLEEVE): Fel Pro 300 (on sleeve)

Hole no.	Hole diameter (in.)						Pull force (lb)	Actual coldwork diameter expansion (in.)	Retained diameter expansion in aluminum (in.)	Retained diameter expansion in titanium (in.)	Remarks
	Before coldwork		After coldwork		Al	Ti					
	Ti	Al	Ti	Al							
A2	0.3605	0.3610	0.3670	0.3695	2800	0.013	0.0085	0.0065	Sleeves easy to remove—sleeve thinout accounts for part of the difference in retained expansion.		
A3	0.3605	0.3610	0.3670	0.3695	2400	0.013	0.0085	0.0065			
A4	0.3605	0.3610	0.3675	0.3695	2300	0.013	0.0085	0.0070			
A5	0.3605	0.3610	0.3670	0.3690	2220	0.013	0.0080	0.0065			
A6	0.3605	0.3610	0.3670	0.3695	2420	0.013	0.0085	0.0065			
A7	0.3605	0.3610	0.3670	0.3695	2400	0.013	0.0085	0.0065			
B1	0.3605	0.3610	0.3670	0.3695	2460	0.013	0.0085	0.0065			
B2	0.3605	0.3610	0.3670	0.3695	2440	0.013	0.0085	0.0065			
B3	0.3605	0.3610	0.3670	0.3695	2460	0.013	0.0085	0.0065			
B4	0.3605	0.3610	0.3675	0.3695	2460	0.013	0.0085	0.0070			

# PHASE I-TASK 5-MULTIMATERIAL STACK PROCESS DATA

SPECIMEN NUMBER: 2V TEST NUMBER: 6 DATE: 12/13/72

MATERIAL COMBINATION: 1 6Al-4V-Ti 2 2024-T851 3 6Al-4V-Ti MANDREL TYPE: ST 5300-CBM-12-0-N

MATERIAL GAGE (IN.) 1 0.285 2 1.00 3 0.285 MANDREL TAPER (IN./IN.): 0.045

NOMINAL HOLE SIZE (IN.) 3/8 MANDREL MAX DIA (IN.): 0.3537

SLEEVE THICKNESS (IN.): 0.010

LUBRICANT (SLEEVE): Fel Pro 300 (on sleeve)

Hole no.	Hole diameter (in.)				Pull force (lb.)	Actual coldwork diameter expansion (in.)	Retained diameter expansion in aluminum (in.)	Retained diameter expansion in titanium (in.)	Remarks
	Before coldwork		After coldwork						
	Ti	Al	Ti	Al					
F1	0.3655	0.3655	0.3650	0.3695	1800	0.008	0.0040	0.0025	Sleeves easy to remove with pliers. Some pulled out with use of fingers.
F2	0.3655	0.3655	0.3650	0.3695	1820	0.008	0.0040	0.0025	
F3	0.3655	0.3650	0.3680	0.3695	1720	0.006	0.0035	0.0025	
F4	0.3655	0.3660	0.3695	0.3695	1860	0.008	0.0035	0.0030	
F5	0.3655	0.3655	0.3680	0.3695	1660	0.008	0.0040	0.0025	
F6	0.3655	0.3650	0.3685	0.3695	1700	0.008	0.0035	0.0030	
G1	0.3655	0.3655	0.3680	0.3695	1680	0.008	0.0040	0.0025	
G2	0.3655	0.3655	0.3685	0.3695	1480	0.008	0.0040	0.0030	
G3	0.3655	0.3660	0.3680	0.3695	1460	0.008	0.0035	0.0025	
G4	0.3655	0.3660	0.3680	0.3695	1460	0.008	0.0035	0.0025	

## PHASE I-TASK 5-MULTIMATERIAL PROCESS DATA

### TEST OBJECTIVE

To determine size differential in aluminum and titanium stack after final ream operation

### TEST CONDITIONS

#### a) Material

- 1) Test plate 1-V consists of 0.0250-in.-thick 2024-T851 plate + 0.250-in.-thick Ti-6Al-4V plate + 0.250-in.-thick 2024-T851 plate (0.75 in. total)
- 2) Test plate 2-V consists of 0.250-in.-thick Ti-6Al-4V plate + 1.00 in.-thick 2024-T851 plate + 0.250-in.-thick Ti-6Al-4V plate.

#### b) Sizing method

- 1) Reaming (0.3735-in. diameter) using TB1 (freon)

### TEST RESULTS

#### a) Test plate 1-V as-reamed hole diameter in inches

2024-T851	Ti-6Al-4V	2024-T851
0.3737	0.3742	0.3742
0.3738	0.3740	0.3740

#### b) Test plate 2-V as-reamed hole diameter in inches

Ti-6Al-4V	2024-T851	Ti-6Al-4V
0.3741	0.3741	0.3742
0.3742	0.3742	0.3745

# PHASE I-TASK 6-SIZING PARAMETERS

Aluminum (2024-T851)-3/8-in. nominal diameter hole in 3/8-in.-thick material, 0.019-in. expansion

Test plate hole no.	Maximum diameter at exit	Typical hole size requirement (in.)	Material to be removed diameter difference (in.)	Comments
D-1	0.370	0.3730 0.3740 0.3730	0.003 min 0.007 max	Reamed five holes with 0.373 reamer; no sign of exit not cleaning up.
D-2	0.369			
D-3	0.370			
D-4	0.370			
E8	0.370			
D8	0.369			
F2	0.371			
F3	0.369			
F4	0.367			
G-1	0.368			

Titanium (Ti-6Al-4V)-3/8-in. nominal diameter hole in 3/8-in.-thick material, 0.019-in. expansion

Test Plate VII hole no.	Maximum diameter at exit	Typical hole size requirement (in.)	Material to be removed diameter difference (in.)	Comments
A1	0.369	0.3730 0.3740 0.3730	0.002 min 0.005 max	Reamed five holes with 0.373 diameter reamer; all holes cleaned up
B1	0.370			
C1	0.370			
D1	0.371			
A2	0.370			
B2	0.370			
C2	0.370			
D2	0.370			
E2	0.370			
F2	0.371			
G2	0.370			

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### APPENDIX III

#### PHASE II DATA

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# A. ALUMINUM

## Task 1 (base metal)

1) 2024-T851

<u>Stress (ksi)</u>	<u>Cycles</u>
30	370,000 510,000 468,000
25	810,000 15,576,000 NF 1,660,000
35	239,000 219,000
40	112,000 143,000

2) 7175-T736

30	8,022,000 8,156,000 10,123,000 NF
----	---

## Task 2 (open holes)

1) 2024-T851

a) Honed holes

30	39,000 46,000 47,000
----	----------------------------

b) Reamed only

30	45,000 47,000 37,000
25	46,000 52,000

20	219,000
35	11,000 10,000 59,000

40	14,000 15,000
----	------------------

c) C/W and postreamed

25	975,000 366,000 12,700,000 NF
35	96,000 114,000

	40	35,000 38,000
2) 7175-T736		
a) Reamed only	30	45,000 56,000 69,000
b) C/W and postreamed	30	510,000 618,000 692,000

Task 3 (ZLT-filled holes)

	<u>Stress (ksi)</u>	<u>Cycles</u>
1) <u>2024-T851</u>		
a) Reamed-net-fit Hi-Loks	30	696,000 565,000 127,000 237,000 205,000
	25	404,000 684,000
	35	82,000 79,000
	40	52,000 49,000
b) C/W and postreamed-net-fit Hi-Loks	30	591,000 950,000 608,000
	25	7,779,000 NF 8,323,000 NF
	35	311,000 387,000
	40	161,000 149,000
c) Protruding-head Taperlok	30	1,236,000 947,000 6,086,000 2,662,000
	25	10,075,000 NF 1,594,000 10,164,000 NF
	35	328,000 369,000

	40	237,000 156,000
d) 100°-flush head Taperlok	30	147,000 264,000 196,000
	25	612,000 661,000
2) <u>7175-T736</u>		
a) Reamed-net-fit Hi-Loks	30	359,000 1,007,000 253,000
b) C/W and postreamed-net-fit Hi-Loks	30	513,000 523,000 293,000

Task 4 (process/application variations)

	<u>Stress (ksi)</u>	<u>Cycles</u>
1) All 2024-T851		
a) <u>Open holes</u>		
90°-sleeve split	30	382,000 424,000 335,000
C/W-as-drilled hole	30	261,000 491,000 226,000
C/W-abusively drilled hole	30	110,000 287,000 93,000
C/W-no postream	30	431,000 333,000 330,000
C/W and score one hole	30	300,000 94,000 393,000
C/W plus 1/64-in. postream	30	235,000 249,000 214,000
C/W plus 1/32-in. postream	30	283,000 256,000 285,000
C/W plus 1/16-in. postream	30	312,000 372,000 226,000

Square wire sleeve	30	167,000 339,000 586,000
0.060-in.-thick material	30	48,000 49,000 65,000
1-1/2D E/M; 5-1/4D hole spacing	30	855,000 203,000 325,000
2D E/M; 5-1/4 SP	30	504,000 535,000 253,000
2-1/2D E/M; 5-1/4 SP	30	756,000 393,000 254,000
2-1/2D E/M; 3D SP	30	339,000 355,000 380,000
2-1/2D E/M; 4D SP	30	300,000 294,000 272,000
b) <u>ZLT-filled holes</u> (net-fit Hi-loks unless otherwise noted)		
One hole not C/W	30	855,000 703,000 325,000
C/W-0.002 clearance, Hi-Lok		694,000 366,000 697,000
C/W-0.000 interference, Hi-Lok		120,000 185,000 250,000
C/W-100°-csk, after		1,247,000 950,000 1,186,000
C/W-100°-csk, before *		169,000 508,000 213,000
C/W-70°-csk, after		290,000 315,000 191,000
C/W--cracked, before		93,000 515,000 625,000

c)	<u>ZLT-15-hole coupon, filled holes</u>		
	C/W and postreamed	40	149,850 150,320 135,990
d)	<u>LLT-15-hole coupon, filled holes</u>		
	C/W and postreamed-one at time	30	265,000 264,000 288,000
	C/W and postreamed-production technique	40	153,000 146,000
		30	273,900
	C/W-no postream-production technique	40	154,600 157,200 165,500
e)	<u>HLT-filled holes</u>		
	C/W-net-fit, 0.010-in. shim	30	580,620 371,350 500,440
	C/W-0.002 clearance, 0.010-in. shim	30	281,720 291,700 355,200
	C/W-0.002 interference, 0.010-in. shim	30	924,180 655,880 900,530
	C/W-net-fit flush-head, 0.010-in. shim	30	508,360* 343,460* 557,400*
	C/W-net fit, no shim	30	294,720 386,990 399,190
	C/W-net fit, no shim, upset removed	30	429,000 674,690 990,370
	Taperlok-0.010-in. shim	30	682,310 741,500 369,400
	Taperlok-flush head, 0.010-in. shim	30	1,422,000* 517,810* 548,000*

\*Test specimen design did not produce evaluation of countersink zone, only shank zone properly evaluated

Reamed only, 0.010-in. shim	30	201,290 151,220 122,060
C/W-0.060-in. shim	30	365,020 867,530

## B. TITANIUM

<u>Task 1 (base metal)</u>	<u>Stress (ksi)</u>	<u>Cycles</u>
1) Ti-6Al-4V (ann)	80	4,051,000 4,200,000
	85	591,000 1,400,000
	95	605,000 1,071,000
	100	188,000 463,000
2) Ti-6Al-4V (STA)	135	35,000
	115	87,000 44,000
3) Ti-6Al-4V (STOA)	115	113,000 97,000 117,000
4) Ti-6Al-6V-2Sn (ann)	115	69,000 53,000 117,000
5) Ti-6Al-6V-2Sn (STA)	115	103,000 90,000 60,000
6) Ti-6Al-6V-2Sn (STOA)	115	189,000 107,000 148,000
<u>Task 2 (open holes)</u>	<u>Stress (ksi)</u>	<u>Cycles</u>
1) Ti-6Al-4V (ann)		
a) Honed holes	65	41,000 66,000 58,000
b) Reamed only	60	67,000 43,000

	65	41,000 39,000
	50	103,000 142,000
	55	420,000 51,000 117,000
c) C/W and postreamed	60	117,000 116,000
	50	1,576,000 6,865,000
	70	70,000 64,000
	65	88,000 104,000
2) Ti-6Al-4V (STA)		
a) Reamed only	70	26,000 30,000 36,000
b) C/W and postreamed	70	81,000 83,000 51,000
3) Ti-6Al-4V (STOA)		
a) Reamed only	70	30,000 32,000 33,000
b) C/W and postreamed	70	70 00 38,000 58,000
4) Ti-6Al-6V-2Sn (ann)		
a) Reamed only	70	51,000 35,000 28,000
b) C/W and postreamed	70	50,000 70,000 79,000
5) Ti-6Al-6V-2Sn (STA)		
a) Reamed only	70	22,000 23,000 24,000

b) C/W and postreamed	70	76,000 94,000 72,000
6) Ti-6Al-6V-2Sn (STOA)		
a) Reamed only	70	38,000 38,000 30,000
b) C/W and postreamed	70	67,000 48,000 55,000
7) Ti-6Al-4V (ann) (3/4-in.-diameter holes)		
C/W and postreamed	70	86,000 54,000 61,000

Task 3 (ZLT-filled holes)

	<u>Stress (ksi)</u>	<u>Cycles</u>
1) Ti-6Al-4V (ann)		
Reamed-net-fit Hi-Loks	70	90,000 83,000 78,000
	75	47,000 52,000
	65	109,000 92,000
	60	246,000 139,000
2) Ti-6Al-4V (STA)		
Reamed-net-fit Hi-Loks	70	65,000 74,000 82,000
3) Ti-6Al-4V (STOA)		
Reamed-net-fit Hi-Loks	70	82,000 74,000 69,000
4) Ti-6Al-6V-2Sn (ann)		
Reamed-net-fit Hi-Loks	70	53,000 43,000 56,000
5) Ti-6Al-6V-2Sn (STA)		
Reamed-net-fit Hi-Loks	70	54,000 48,000 29,000

6) Ti-6Al-6V-2Sn (STOA)		
Reamed-net-fit Hi-Loks	70	70,000 52,000 51,000
Ti-6Al-4V (ann)		
C/W and postreamed with net-fit Hi-Loks	70	1,830,000 347,000 698,000
	65	1,333,000 2,273,000
	75	203,000 199,000
	80	180,000 137,000
7) Ti-6Al-4V (STA)		
C/W and postreamed with net-fit Hi-Loks	70	509,000 468,000 545,000
9) Ti-6Al-4V (STOA)		
C/W and postreamed with net-fit Hi-Loks	70	1,580,000 616,000 146,000
10) Ti-6Al-6V-2Sn (ann)		
C/W and postreamed with net-fit Hi-Loks	70	530,000 487,000 195,000
11) Ti-6Al-6V-2Sn (STA)		
C/W and postreamed with net-fit Hi-Loks	70	143,000 99,000 110,000
12) Ti-6Al-6V-2Sn (STOA)		
C/W and Postreamed with net-fit Hi-Loks	70	197,000 90,000 147,000
13) Ti-6Al-4V (ann)		
a) Protruding-head Taperloks	70	367,000 689,000 5,323,000
	75	3,086,000 10,061,000

	65	7,788,000 NF 7,774,000 NF
	60	300,000 7,602,000 NF
b) Flush-head Taperloks	70	1,146,000 240,000 370,000
	75	372,000 99,000
	65	266,000 563,000
	60	1,092,000 2,602,000

Task 4 (process/application variations)

1) (all Ti-6Al-4V (ann))

a) Open holes

90°-sleeve split (C/W)	70	179,000 87,000 79,000
C/W as-drilled hole	70	63,000 66,000 66,000
C/W—abusively drilled hole	70	47,000 43,000 54,000
C/W—no postream	70	79,000 88,000 82,000
C/W—score, one hole	70	85,000 72,000 76,000
C/W plus 1/64-in. postream	70	61,000 64,000 64,000
C/W plus 1/32-in. postream	70	54,000 76,000 67,000
C/W plus 1/16-in. postream	70	62,000 67,000 54,000

C/W square wire sleeve (no results, see data sheet)			
0.060-in.-thick material	C/W plus postream	70	61,000 50,000 61,000
1-1/2D E/M; 5-1/4D hole spacing	C/W plus postream	70	46,000 90,000 68,000
2D E/M; 5-1/4D hole spacing	C/W plus postream	70	49,000 56,000 52,000
2-1/2D E/M; 5-1/4D hole spacing	C/W plus postream	70	67,000 63,000 62,000
2-1/2D E/M; 3D hole spacing	C/W plus postream	70	58,000 81,000 74,000
2-1/2D E/M; 4D hole spacing	C/W plus postream	70	59,000 104,000 66,000
b) Filled holes (ZLT) -(net-fit Hi-Loks unless otherwise noted)			
One hole not C/W		70	119,000 77,000 1,286,000
C/W-0.002-in. clearance, Hi-Lok		70	153,000 226,000 179,000
C/W-0.002-in. interference, Hi-lok		70	4,421,000 6,836,000 824,000
C/W-csk after		70	217,000 212,000 483,000
C/W-csk before		70	760,000 757,000 1,064,000
C/W-70	C/W-70°-csk after	70	555,000 570,000 435,000

C/W—prefatigued	70	709,000 431,000
C/W—cracked before	70	312,000 92,000 782,000
c) ZLT—15-hole coupon, filled holes		
C/W postreamed	70	124,450 122,210 60,780
d) LLT—15-hole coupon, filled holes		
C/W and postreamed—production technique	70	40,190 31,840 47,330
C/W, no postreamed—production technique	70	98,040 187,150 191,330
C/W, postreamed—2024-T851 stringer plus Ti-6Al-4V (ann) skin	40(Al) 64(Ti)	61,590 79,170 64,620
e) HLT—filled holes		
C/W-net-fit, 0.010 shim	70	21,280 22,500 17,340
C/W-0.002-in. clearance, 0.010-in. shim	70	18,660 20,640 20,000
C/W-0.002-in. interference, 0.010-in shim	70	24,140 24,700 26,630
C/W-net-fit, flush head, 0.010-in. shim	70	11,580 6,200 11,170
C/W—net-fit, no shim	70	30,700 39,950 33,630
C/W—net-fit—no shim, upset removed	70	98,140 36,180 31,890
Taperlok --protruding head, 0.010-in. shim	70	73,970 78,490 62,280

Taperlok--flush head, 0.010 shim

70 9,590  
8,450  
8,740

Reamed only--net-fit Hi-Lok

70 19,050  
18,060  
10,940

C. 300M STEEL (270/300 KSI)

Task 1 (base metal)

<u>Stress (ksi)</u>	<u>Cycles</u>
110	10,000,000 NF 10,000,000 NF
120	10,000,000 NF
130	591,000 177,000 2,558,000
135	364,000
140	84,000 114,000

Task 2 (open holes)

a) Honed holes

105 43,000  
34,000  
42,000

b) Reamed only

100 113,000  
400,000  
105 139,000  
103,000  
75,000

110 48,000  
60,000

115 32,000  
49,000

c) C/W and postreamed

100 99,000  
132,000

105 54,000  
72,000  
71,000

110 41,000  
62,000

	115	127,000
		46,000
d) C/W and postreamed 3/4-in.-diameter holes	100	100,000
		75,000
		210,000

### Task 3 (ZLT-filled holes)

	<u>Stress (ksi)</u>	<u>Cycles</u>
a) Reamed only plus net-fit Hi-Loks	100	112,000
		237,000
	105	97,000
		136,000
	110	76,000
		90,000
		62,000
	115	40,000
		51,000
b) C/W and postreamed with net-fit Hi-Loks (0.045 in./in. mandrels taper)	100	673,000
		8,300,000
	105	462,000
		4,203,000
	110	141,000
		382,000
		252,000
c) C/W and postream with net fit Hi-Loks (0.030 in./in. mandrel taper)	110	390,000
		349,000
		264,000
d) C/W and postream with netfit Hi-Loks (0.045 in./in. mandrel taper) (0.005 in. less interference)	110	121,000
		118,000
		105,000
e) C/W and postream with net fit Hi-Loks (0.015 in./in. mandrel taper)	110	287,000
		364,000
		76,000

### Task 4 (process/application variations)

	<u>Stress (ksi)</u>	<u>Cycles</u>
a) <u>Open holes</u>		
0°-sleeve process	110	93,000
		280,000
		178,000

90°-split sleeve process	110	163,000
		128,000
		114,000
C/W -no postream	110	428,000
		388,000
		208,000
C/W -score, one hole	110	103,000
		67,000
		110,000
C/W -as-drilled hole	110	266,000
		152,000
		252,000
C/W -abusively drilled holes	110	113,000
		150,000
		380,000
C/W plus 1/64-in. postream	110	65,000
		45,000
		59,000
C/W plus 1/32-in. postream	110	248,000
		121,000
		209,000
C/W plus 1/16-in. postream	110	58,000
		72,000
		55,000
0.060-in.-thick material	110	71,000
		12,000
		47,000
1-1/2D E/M; 5-1/4D hole spacing	110	100,000
		170,000
		177,000
2D E/M; 5-1/4D hole spacing	110	78,000
		44,000*
		56,000*
2-1/2D E/M; 5-1/4D hole spacing	110	70,000
		72,000
		182,000
2-1/2D E/M; 3D hole spacing	110	91,000
		80,000
		116,000

\*Grip failed

2-1/2D E/M; 4D hole spacing	110	120,000 145,000 143,000
b) <u>ZLT-filled holes</u> (net-fit Hi-Loks unless otherwise noted)		
One hole, not C/W	110	43,000 52,000 33,000
C/W - 0.002-in. clearance, Hi-Lok	110	711,000 254,000 283,000
C/W - 0.002-in. interference, Hi-Lok	110	3,282,000 198,000 244,000
C/W - 100°-csk after	110	9,993,000 NF 7,760,000 NF 1,510,000
C/W - 70°-csk after	110	935,000 420,000 2,547,000
C/W - 100°-csk before	110	38,000 26,000 36,000
C/W - prefatigued	110	343,000 7,508,000 NF
C/W - cracked before	110	7,484,000 NF 486,000
c) <u>HLT-filled holes</u> (Hi-Loks)		
C/W - net-fit, 0.020-in. shim	110	18,830 17,240 13,750
C/W - 0.002-in. clearance-fit, 0.020-in. shim	110	14,850 21,820 17,150
C/W - 0.002-in. interference fit, 0.020-in. shim	110	20,350 15,040 21,930
C/W - net fit, flush head, 0.020-in shim, side plates reduced to 0.125 in. thick	110	7,910 8,090 9,300

	<u>Stress</u>	<u>Cycles</u>	<u>Stress*</u>	<u>Cycles</u>
Reamed only 0.020-in. shim	110	4,220	110	4,220
	95	8,040	110	2,500
	95	9,320	110	3,000
C/W-net fit, no shim	122	7,150	110	10,000
	122	9,660	110	15,000
	122	11,770	110	20,000

\*Values converted to 110 ksi stress

# PHASE II TASK 1 - BASE METAL VALUES

TEST NUMBER: II Base

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 1-15-73

### 1. Specimen Description

Zero load transfer  
Configuration: Fig. 2  
Width: 1.50"  
Hole spacing: -  
Edge margin: -  
Material: 2024 T 851  
Material gauge: 0.250"  
Surface Treatment: Shot Peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: -  
Sleeve orientation: -  
CW Mandrel: 0.0M- -0-N  
CW M: -  
Major Dia.: -  
Surface: Fel Pro 300 (on sleeve)

**NOT APPLICABLE**



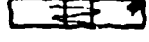
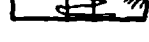
### 2. Hole Preparation

Nominal hole size: -  
Process: -

2024  
Base Metal  
30 ksi

### 4. Fatigue Conditions

Net stress: 30 ksi  
Test load: 10,500 lbs  
Load ratio: (R) = 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophore (36 Kip)

Specimen No. R623077	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-1										370	
-2										510	
-3										468	

NO HOLES

 Taken at Minimum (midpoint)

# PHASE II TASK I - BASE METAL VALUES

TEST NUMBER: II BASE

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 1-15-73

### 1. Specimen Description

Zero load transfer:  
Configuration: Fig 2  
Width: 1.50"  
Hole spacing: -  
Edge margin: -  
Material: 2024 T 851  
Material gauge: 0.250"  
Surface Treatment: Shot Peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: -  
Sleeve orientation: -  
CW Mandrel: 0.001" - 0.002"  
CW M: -  
Major Dia.: -  
Surface: Fel Pro 300 (on sleeve)

### 2. Hole Preparation

Nominal hole size: -  
Process: -

2024  
Base Metal  
25 ksi

### 4. Fatigue Conditions

Net stress: 25 ksi  
Test load: 9,600 lbs  
Load ratio: (R) = 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophore (36 Kip)

Specimen No. R623077	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After ream	Before CW	After CW	After Ream				
-4										810	
-5										15,576 NF	 No Failure
-10										1,660	

1 - Taken at Midpoint (midpoint)

# PHASE II TASK 1 - BASE METAL VALUES

TEST NUMBER: II Base  
 NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 1-15-73

### 1. Specimen Description

Zero load transfer  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: -  
 Edge margin: -  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: -  
 Sleeve orientation: -  
 CW Mandrel: 0.000" -0-N  
 CW M: -  
 Major Dia.: -  
 Fel Pro 300 (on sleeve)

**NOT APPLICABLE**


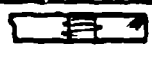
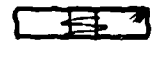

### 2. Hole Preparation

Nominal hole size: -  
 Process: -

2024  
 Base Metal  
 35 ksi

### 4. Fatigue Conditions

Net stress: 35 ksi  
 Test load: 11,750 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophone (36 Kip)

Specimen No. R623077	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-6										239	
-7										219	
											

NO HOLES

1 - Taken at Minimum (midpoint)

# PHASE II TASK 1 - BASE METAL VALUES

TEST NUMBER: II Base

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 1-15-73

### 1. Specimen Description

Zero load transfer  
Configuration: Fig. 2  
Width: 1.50"  
Hole spacing: -  
Edge margin: -  
Material: 2024 T 851  
Material gauge: 0.250"  
Surface Treatment: Shot Peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: -  
Sleeve orientation: -  
CW Mandrel: - -0-N  
CW M: -  
Major Dia.: -  
Fel Pro 300 (on sleeve)

NOT APPLICABLE -





### 2. Hole Preparation

Nominal hole size: -  
Process: -

2024  
Base Metal  
40 ksi

### 4. Fatigue Conditions

Net stress: 40 ksi  
Test load: 12,500 lbs  
Load ratio: (R) = 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophore (36 Kip)

Specimen No. R623077	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-8										112	
-9										143	
											

NO HOLES -

 Taken at Minimum (midpoint)

# PHASE II TASK 1 - BASE METAL VALUES

TEST NUMBER: BASE (7175 T736)

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 4-5-73

### 1. Specimen Description

Zero load transfer  
Configuration: Fig. 2  
Width: 1.50"  
Hole spacing: -  
Edge margin: -  
Material: 7175 T736  
Material gauge: 0.250"  
Surface Treatment: Shot Peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: -  
Sleeve orientation: -  
CW Mandrel: UM - -0-N  
CW M: -  
Major Dia.: -  
Surface: Fel Pro 300 (on sleeve)


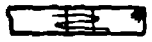

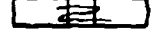
### 2. Hole Preparation


Nominal hole size: -  
Process: -

7175  
Base Metal

### 4. Fatigue Conditions

Net stress: 30 ksi  
Test load: 11,250 lbs  
Load ratio: (R) 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophore (36 Kip)

Specimen No. R623077	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-1										8,022	
-2										8,156	
-3										10,123 NF	

 Taken at Minimum (independent)

NO HOLES

# PHASE II - TASK 1 - BASE METAL VALUES

Ti 6Al 4V (annealed)  
base metal  
80 ksi

TEST IT1 SPECIMEN 623077 DATE 8/16/73

## SPECIMEN DESCRIPTION

Configuration Fig. 2  
Material Ti 6Al 4V (annealed)  
Width (in) 1.50  
Hole spacing -  
Edge margin (in) -  
Material gauge (in) 0.250  
Surface treatment Shot Peen

## COLDWORK PROCESS

Interference -  
Sieve type -  
Sieve thickness (in) -  
Sieve orientation -  
Mandrel material -  
Mandrel taper (in/in) -  
Mandrel max diameter (in) -  
Lubrication -

## HOLE PREPARATION

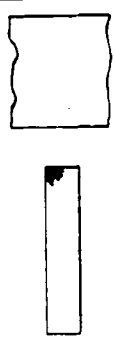
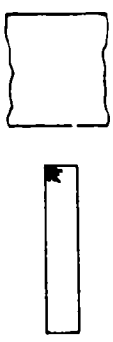
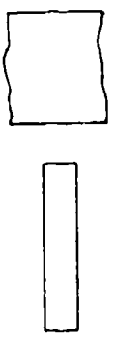
Nominal hole size (in) -  
Process -

## FASTENER INSTALLATION

Type -  
Fit -  
Torque (in/lb) -

## FATIGUE CONDITIONS

Max net stress (ksi) 80  
Max test load (kip) 30.5  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 100 kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in)			Hole finish (RHR)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
1	1											4,051,000	 Failed at radius intersection
	2												
	3												
	4												
2	1											4,200,000	 Failed at radius intersection
	2												
	3												
	4												
	1												 Failed at radius intersection
	2												
	3												
	4												

# PHASE II - TASK 1 - BASE METAL VALUES

Ti-6Al-4V (annealed)  
base metal  
85 ksi

TEST IT2 SPECIMEN 623077 DATE 8/16/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference		Nominal hole size (in.)		Max. net stress (ksi)	85
Material	Ti-6Al-4V (annealed)	Sleeve type		Process		Max. test load (kip)	33
Width (in.)	1.50	Sleeve thickness (in.)				Load ratio (R)	0.1
Hole spacing		Sleeve orientation				Test frequency	4000 cpm
Edge margin (in.)		Mandrel material				Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)				Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)				Test machine	100 kip Vibraphore
		Lubrication					

## FASTENER INSTALLATION

Type

Fit

Torque (in.-lb)

Specimen dash no.	Hole no.	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
4	1											591,000	Failed at radius intersection
	2												
	3												
	4												
5	1											1,400,000	Failed at radius intersection
	2												
	3												
	4												
	1												Failed at radius intersection
	2												
	3												
	4												

Ti 6Al 4V (annealed)  
base metal  
95 ksi

TEST IT3 SPECIMEN 623077 DATE 8/16/73

## SPECIMEN DESCRIPTION

**Fig. 2**

Ti-6Al-4V | annealed

Width (in.)

**Note: spacing**

Edge margin (in)

0.750

Shotpeen

\_\_\_\_\_

## COLDWORK PROCESS

Slaves, you

Solve this cross (in 1)

## Stress Orientation

**Mantrel material**

Mandrel taper (in/in)

Mandrel max diameter (in)

110-15-0111

## HOIE PREPARATION

Nominal hole size (in.)

## Process

## FASTENER INSTALLATION

**Typing**

33

Torque (in. lbs)

## FATIGUE CONDITIONS

Max test load (kip)

Load ratio (R)

Test frequency

## Test laboratory

**Test engineer**  
**D. Heese**

Test machine  
100-kip Vibraphone

[illegible]

# PHASE II - TASK 1 - BASE METAL VALUES

Ti 6Al 4V (annealed),  
base metal  
100 ksi

TEST IT4 SPECIMEN 623077 DATE 8/16/73

## SPECIMEN DESCRIPTION

Configuration Fig. 2  
Material Ti 6Al 4V (annealed)  
Width (in) 1.50  
Hole spacing -  
Edge margin (in) -  
Material gauge (in) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS

Interference -  
Sleeve type -  
Sleeve thickness (in) -  
Sleeve orientation -  
Mandrel material -  
Mandrel taper (in/in) -  
Mandrel max diameter (in) -  
Lubrication -

## HOLE PREPARATION

Nominal hole size (in) -  
Process -  
FASTENER INSTALLATION  
Type -  
Fit -  
Torque (in. lb) -

## FATIGUE CONDITIONS

Max net stress (ksi) 100  
Max test load (kip) 39  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 100 kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in)		Hole finish (RHR)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
8	1										188,000	Failed at radius intersection
	2											
	3											
	4											
9	1										463,000	Failed at radius intersection
	2											
	3											
	4											
	1											Failed at radius intersection
	2											
	3											
	4											

Ti-6Al-4V (sta),  
base metal  
135 ksi

TEST \_\_\_\_\_ ITS \_\_\_\_\_ SPECIMEN 623077 DATE 8/16/73

## SPECIMEN DESCRIPTION

Configuration	Fig. 2
Material	Ti-6Al 4V (sta)
Width (in.)	1.50
Hole spacing	-
Edge margin (in.)	0.250
Material gauge (in.)	Shot peen
Surface treatment	

## COLLOWORK PROCESS

Interference  
Sleeve type  
Sleeve thickness (in.)  
Sleeve orientation  
Mandrel material  
Mandrel taper (in./in.)  
Mandrel maximum diameter  
Lubrication

## WHOLE PREPARATION







Nominal Hole Size (in.)	_____
Process	_____
STENER INSTALLATION	
Type	_____
Fit	_____
Torque (in. ft.)	_____

## FASTEN#8 INSTALLATION

Type	Force	Torque (in lb.)
1	100	100
2	200	200
3	300	300
4	400	400
5	500	500
6	600	600
7	700	700
8	800	800
9	900	900
10	1000	1000

## FATIGUE CONDITIONS

Max. net stress (ksi)	135
Max. test load (kip)	45
Load ratio (R)	0.1
Test frequency	4000 cpm
Test laboratory	Materials
Test engineer	D. Reese
Test machine	100-kip Vibration

Specimen dash no	Hole no	Hole diameter (in )			Hole finish (RHII)			Collarwork expansion (in )		Fastener size (in )		Cycles to failure	Origin of failure and remarks	
		Before collarwork	After collarwork	After ream	Before collarwork	After collarwork	After ream	Actual	Retained	Diameter	Fit			
1 sta	1											35,000		
	2													
	3													
	4													
2 sta	1											87,000		
	2													
	3													
	4													
3 sta	1											44,000		
	2													
	3													
	4													
													Failed at radius intersection	
													Failed at radius intersection	

# PHASE II - TASK 1 - BASE METAL VALUES

Ti 6Al-4V (stoal),  
base metal,  
115 ksi

TEST IT6 SPECIMEN 623077 DATE 8/16/73

## SPECIMEN DESCRIPTION

Fig. 2

Configuration Ti 6Al-4V (stoal)  
Material 1.50  
Width (in) 0.250  
Hole spacing Shot (peen)  
Edge margin (in)  
Material gauge (in)  
Surface treatment

## COLDWORK PROCESS

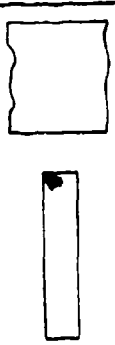


Interference  
Sleeve type  
Sleeve thickness (in)  
Sleeve orientation  
Mandrel material  
Mandrel taper (in/in)  
Mandrel max diameter (in)  
Lubrication

## HOLE PREPARATION

Nominal hole size (in)  
Process  
FASTENER INSTALLATION  
Type  
Fit  
Torque (in ft)

## FATIGUE CONDITIONS

Max net stress (ksi) 115  
Max test load (kip) 43  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 100-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in)				Hole finish (RHR)				Coldwork expansion (in)			Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	After coldwork	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit				
1 stoal	1														113,000	
	2															
	3															
	4															
2 stoal	1														97,000	
	2															
	3															
	4															
3 stoal	1														117,000	
	2															
	3															
	4															

Failed at radius intersection

Ti-6Al-6V-2Sn (annealed),  
base metal,  
115 ksi

TEST \_\_\_\_\_ IT7 \_\_\_\_\_ SPECIMEN 623077 DATE 9/20/73

## SPECIMEN DESCRIPTION

**Configuration**

Ti-6Al 6V2Sn (annealed)

1.50

Hole spacing q

Edge margin (in )

0.250

### Surface treatment

## COLDWORK PROCESS

## Interference

**Sleeve type .**

Sleeve thickness (in.)

**Sleeve orientation.**

**Manichel material**

Mandrel taper (in./in.)

Mandrel max diameter (in)

**Lubrication**

## HOLE PREPARATION

Nominal hole size (in.)

## Process

## FASTENER INSTALLATION

Type

F.18

**Force (in lb)**

## FATIGUE CONDITIONS

Max net stress (ksi)

Max test load (kip)	44.4
Max test load (kN)	197.8

Load ratio (R)	0.1
----------------	-----

Test frequency

## Test laboratory

**Test engineer**  
**D. Reese**

**Tax machine**  
**100-kip Vibraphore**

[illegible]

# PHASE II - TASK 1 BASE METAL VALUES

Ti-6Al-6V-2Sn (sta),  
base metal,  
115 ksi

TEST ITB SPECIMEN 623077 DATE 9/20/73

## SPECIMEN DESCRIPTION

Configuration Fig. 2  
Material Ti-6Al-6V-2Sn (sta)  
Width (in) 1.50  
Hole spacing -  
Edge margin (in) -  
Material gage (in) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS

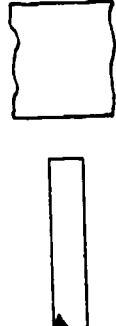


Interference -  
Sleeve type -  
Sleeve thickness (in) -  
Sleeve orientation -  
Mandrel material -  
Mandrel taper (in/in) -  
Mandrel max diameter (in) -  
Lubrication -

## HOLE PREPARATION

Nominal hole size (in) -  
Process -  
FASTENER INSTALLATION  
Type -  
Fit -  
Torque (in-lb) -

## FATIGUE CONDITIONS

Max net stress (ksi) 115  
Max test load (kip) 43.2  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 100-kip Vibrashore

Specimen dash no	Hole no	Hole diameter (in )			Hole finish (RHRI)			Coldwork expansion (in )		Fastener size (in )		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
1. 662 stu	1											103,000	 Failed at radius blend
	2												
	3												
	4												
3. 662 sta	1											90,000	 Failed at radius blend
	2												
	3												
	4												
3. 662 sta	1											60,000	 Failed at radius blend
	2												
	3												
	4												

Ti 6Al 6V2Sn (stoa).  
base metal.  
115 ksi

TEST IT9 SPECIMEN 623077 DATE 9/20/73

## COLDWORK PROCESS

Fig. 2

Ti-6Al-6V-2Sn (stoal)

Width (in)

**Hole spacing**

Edge margin (in)

Material concn (i.e.)

Surface treatment

## HOLE PREPARATION

Nominal hole size (in.)

## Process

Sleeve thickness (in.)

### Sleeve orientation.

### Manurel material

**Mandel, James H.**

Mandel max diameter

## Lubrication

## FASTENER INSTALLATION

Type:

819

Torque (in lb)

## FATIGUE CONDITIONS

115

Max test load (kN)

44

Load ratio (R) 0.1

Test frequency : 4000 cpm

**Test laboratory** .

**Materials** \_\_\_\_\_

D. Reese  
Test engineer

Test machine . . . . . 100 kip Vibraphore


[illegible]

# PHASE II - TASK 1 - BASE METAL VALUES

300 M, Base Metal, 110 KSI

TEST: 1A - SPECIMEN: 623077 DATE: 6/11/73

SPECIMEN DESCRIPTION		COLLWORK PROFILES		HOLE PREPARATION		FATIGUE CONDITIONS	
Fig. 2		Interference		Normal beam size (in.)		Stress (ksi)	
Configuration	300 M steel (2700-3000 ksi)	Sleeve type		Process		Max test load (kip)	
Material	1.50	Sleeve thickness (in.)				Load ratio (R)	
Width (in.)		Sleeve orientation				Test frequency	
Hole spacing		Manhole material		FASTENER INSTALLATION		Test laboratory	
Edge margin (in.)	0.250	Manhole taper (in./in.)		Type		Test equipment	
Material type (in.)	Shot peen	Manhole max diameter (in.)		Fit		Test machine	
Surface treatment		Lubrication		Torque (in. lb)			

Specimen ref no	Hole no	Hole diameter (in.)				Hole finish (RHRI)				Collwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before collwork	After collwork	After ream	Before collwork	After collwork	After ream	Actual	Retained	Diameter	Fit				
-1	1													364,000	
	2														
	3														
	4														135 ksi (net stress)
-2	NO HOLES													1,000,000	No failure
	4														110 ksi (net stress)
-3	1													1,000,000	No failure
	2														
	3														
	4														110 ksi (net stress)

PHASE II - TASK 1 - BASE METAL VALUES

300 M. Base Metal, 140 KSI

TEST 18 SPECIMEN 623077 DATE 6/11/73

SPECIMEN DESCRIPTION

Fig 2

COLDWORK PROCESS

HOLE PREPARATION

FATIGUE CONDITIONS

Configuration: Fig 2 Interference:            Nominal hole size (in):            Max net stress (ksi): 140

Material: 300 M steel (270-300 ksi) Sleeve type:            Process:            Max test load (kip): 52

Width (in): 1.50 Sleeve thickness (in):            Sleeve orientation:            Load ratio (R): 0.1















Hole spacing:            Material material:            Material (after (in in)):            Test frequency: 4300 SPD

Edge margin (in): 0.250 Material material:            Material max diameter (in):            Type:            Test labor flow: Materials

Material gap (in):            Material max diameter (in):            Type:            Test engineer: D. Reese

Surface treatment: Shot blast Material max diameter (in):            Type:            Test machine: 100 kip Vibrophor

Lubrication:            Torque (in lb):           

Specimen dash no	Hole no	Hole diameter (in)			Hole finish (HRH)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Discrepancy	F/I		
-4	1											84,000	<div></div> <div></div>
	2												<div></div> <div></div>
	3												
-5	NO HOLES											114,000	<div></div> <div></div>
	4												<div></div> <div></div>
	1												<div></div> <div></div>
	2												
	3												<div></div> <div></div>
	4												<div></div> <div></div>

PHASE II - TASK 1 - BASE METAL VALUES  
300 M Base Metal 120 KSI

TEST 1C SPECIMEN 623077 DATE 6/11/73

SPECIMEN DESCRIPTION

Fig. 2

Configuration

Material 300 M steel (270-300 ksi)

Width (in) 1.50

How welded

Edge margin (in)

Material gauge (in) 0.250

Surface treatment Shot peen

COLDWORK PROCESS

Interference

Sleeve type

Sleeve thickness (in)

Sleeve orientation

Manifold material

Manifold taper (in/in)

Manifold max diameter (in)

Lubrication

HOLE PREPARATION

Nominal hole size (in)

Process

FASTENER INSTALLATION

Type

F<sub>t</sub>

Torque (in lb)

FATIGUE CONDITIONS

Max net stress (ksi) 120

Max test load (kip) 46.3


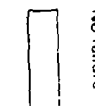


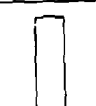

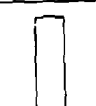
Load ratio (R) 0.1

Test frequency 4300 cpm

Test laboratory Materials

Test engineer D. Reese

Test machine 100 kip Vibration

Specimen dash no	Hole no	Hole diameter (in)			Hole finish (RHH)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks	
		Before coldwork	After coldwork	After resin	Before coldwork	After coldwork	After resin	Actual	Retained	Diameter	F-t			
-6	1											1,000,000	No failure	
	2													
	3													
	4													
	NO HOLES													
	1													
	2													
	3													
	4													

# PHASE II - TASK 1 - BASE METAL VALUES

300 M Base Metal 130 KSI

TEST ID SPECIMEN 623077 DATE 6/11/73

## SPECIMEN DESCRIPTION

Fig. 2

Configuration  
Material 300 M steel (270-300 ksi)  
Width (in) 1.50  
Hole spacing  
Edge margin (in) 0.250  
Material grade (in) Shot green  
Surface treatment

## COLDWORK PROCESS







Interference  
Sleeve type  
Sleeve thickness (in)  
Sleeve orientation  
Mandrel material  
Mandrel taper (in/in)  
Mandrel max diameter (in)  
Lubrication

## HOLE PREPARATION

Nominal hole size (in)  
Process  
FASTENER INSTALLATION  
Type  
Torque (in-lb)

## FATIGUE CONDITIONS

130  
Max net stress (ksi)  
Max test load (kip)  
Load ratio (R)  
Test frequency  
Test laboratory  
Test engineer  
Test machine

Specimen Label no	Hole no	Hole diameter (in)			Hole finish (RHR)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	F <sub>1</sub>		
-7	1											591,000	 
	2												
	3												
-8	NO HOLES												177,000  
	1												
	2												
-9	1											2,558,000	 
	2												
	3												
	1												
	2												
	3												

# PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: II A 1  
 NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 1-30-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T.851  
 Material gauge: 0.375"  
 Surface Treatment: Shot Peen  
 Fastener: None

### 3. CW Process

Sleeve type: Axial  
 Sleeve thickness: 0.00  
 Sleeve orien: 0°  
 CW Mn: 500-CBM-  
 CW per: -0-1  
 Major Dia.: -  
 Fin: Fel Pro 300 (on sleeve)

**NOT APPLICABLE**



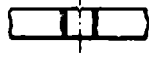
### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Drill, ream, Hone

### 4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,500 lbs.  
 Load ratio: (R) 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 KIP)

2024  
 Honed Open  
 30 ksi

Specimen No. R-623078	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
				After Hone			After Hone				
-1	1	-	-	.3755	-	-	25	-	-	39	
	2	-	-	.3755	-	-	25	-	-		
-2	1	-	-	.3760	-	-	25	-	-	46	
	2	-	-	.3760	-	-	25	-	-		
-3	1	-	-	.3755	-	-	20	-	-	47	
	2	-	-	.3755	-	-	20	-	-		

1 Taken at Minimum (midpoint)

# PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: II A 2

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 1-30-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 2  
Width: 1.50"  
Hole spacing: 1.50"  
Edge margin: 0.75"  
Material: 2024 T 851  
Material gauge: 0.375"  
Surface Treatment: Shot Peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial  
Sleeve thickness: 0.00  
Sleeve orientation: 00  
CW M: 00-CBM- -(0-N)  
per: -  
Major Dia.: -  
Location: Fel Pro 300 (on sleeve)

**NOT APPLICABLE**





### 2. Hole Preparation

Nominal hole size: 3/8"  
Process: Drill & Ream

### 4. Fatigue Conditions

Net stress: 30 ksi  
Test load: 8,500 lbs.  
Load ratio: (R) 0.1  
Test Frequency: 5,000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophore (36 Kip)

2024  
Reamed Open  
30 ksi

Specimen No. R-623078	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-5	1	-	-	.3760	-	-	40	-	-	45	
	2	-	-	.3760	-	-	50	-	-		
-6	1	-	-	.3765	-	-	50	-	-	47	
	2	-	-	.3765	-	-	50	-	-		
-7	1	-	-	.3760	-	-	45	-	-	37	
	2	-	-	.3760	-	-	50	-	-		

 Taken at Minimum (midpoint)

# PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: 2A

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 3-9-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

### 3. CW Process

Sleeve type:             
 Sleeve thickness:             
 Sleeve orifice:             
 CW Material:             
 CW Process:             
 Major Dia.:           

**NOT APPLICABLE**




### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream

2024  
 Reamed Open  
 20 ksi

### 4. Fatigue Conditions

Net stress: 20 ksi  
 Test load: 5,675 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore 36 Kip)

Specimen No. R623078	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-14	1	.3760			65	59	 35 ksi (Net Stress)
	2	.3765			65		
-21	1	.3730			30	219	 C/W
	2	.3720			30		
-	1						
	2						

# PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: II A 3

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 1-30-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 2  
Width: 1.50"  
Hole spacing: 1.50"  
Edge margin: 0.75"  
Material: 2024 T 851  
Material gauge: 0.375"  
Surface Treatment: Shot Peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial  
Sleeve thickness: -  
Sleeve ori: 0°  
CW M: 300-CBM- -0-N  
Super: -  
el Major Dia.: -  
ation: Fel Pro 300 (on sleeve)

**NOT APPLICABLE**




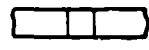
### 2. Hole Preparation

Nominal hole size: 3/8"  
Process: Drill & Ream

### 4. Fatigue Conditions

Net stress: 25 ksi  
Test load: 7000 lbs.  
Load ratio: (R) - 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophone (36 Kip)

2024  
Reamed Open  
25 ksi

Specimen No. R-623078	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-8	1	-	-	.3760	-	-	60	-	-	46	
	2	-	-	.3760	-	-	55	-	-		
-9	1	-	-	.3760	-	-	45	-	-	52	
	2	-	-	.3760	-	-	55	-	-		
											

1 - Taken at Maximum (midpoint)

# PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: II A 4

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 1-30-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.375"  
 Surface Treatment: Shot Peen  
 Fastener: None

### 3. CW Process

Sleeve type: Av  
 Sleeve thick: 0.00  
 Sleeve: 0.00  
 CW: 5300-CBM- -0-N  
 taper: 0.00  
 andrel Major Dia.: 0.00  
 orication: Fel Pro 300 (on sleeve)

**NOT APPLICABLE**




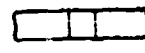
### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Drill & Ream

### 4. Fatigue Conditions

Net stress: 35 ksi  
 Test load: 9950 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

2024  
 Reamed Open  
 35 ksi

Specimen No. R-673078	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-10	1	-	-	.3760	-	-	50	-	-	11	
	2	-	-	.3760	-	-	60	-	-		
-11	1	-	-	.3760	-	-	30	-	-	10	
	2	-	-	.3760	-	-	50	-	-		
											

1 - Taken at Minimum (midpoint)

# PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: 11 A4 (a)

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 3-9-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

### 3. CW Process

Sleeve type: -  
 Sleeve thickness: -  
 Sleeve or: -  
 CW M: -  
 C: -  
 Paper: -  
 Hole Major Dia.: -  
 Location: -

**- NOT APPLICABLE -**



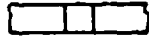
### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream

### 4. Fatigue Conditions

Net stress: 35 ksi  
 Test load: 10,000 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

2024  
 Reamed Open  
 35 ksi

Specimen No. R623078	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-11A	1	.3732			25	27	
	2	.3732			-		
-12A	1	.3733			25	28	
	2	.3733			-		
-	1						
	2						

# PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: IIA 5

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 1-30-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 2  
Width: 1.50"  
Hole spacing: 1.50"  
Edge margin: 0.75"  
Material: 2024 T 851  
Material gauge: 0.375"  
Surface Treatment: Shot Peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial  
Sleeve thickness: -  
Sleeve orient: 0°  
CW Mor: CU-CBM -0-N  
CW per: -  
Major Dia.: -  
Material: Fel Pro 300 (on sleeve)

- NOT APPLICABLE -





### 2. Hole Preparation

Nominal hole size: 3/8"  
Process: Drill & Ream

### 4. Fatigue Conditions

Net stress: 40 ksi  
Test load: 11,500 lbs.  
Load ratio: (R) - 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophone (36 Kip)

2024  
Reamed Open  
40 ksi

Specimen No. R-623078	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-12	1	-	-	.3760	-	-	50	-	-	14	
	2	-	-	.3760	-	-	100	-	-		
-13	1	-	-	.3760	-	-	100	-	-	15	
	2	-	-	.3765	-	-	80	-	-		
											

[T] > Taken at Midpoint (mid-point)

# PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: 11A6

NOMINAL EXPANSION VALUE: 0.0185-0.020

## GENERAL TEST CONDITIONS

DATE: 12-19-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 2  
Width: 1.50"  
Hole spacing: 1.50"  
Edge margin: 0.75"  
Material: 2024 T 851  
Material gauge: 0.250"  
Surface Treatment: Shot Peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.010"  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM-12 -0-N  
CW Mandrel Taper: 0.045"/"  
CW Mandrel Major Dia.: 0.354"  
Lubrication: Fel Pro 300 (on sleeve)





### 2. Hole Preparation

Nominal hole size: 3/8"  
Process: Drill, ream, CW & ream

### 4. Fatigue Conditions

Net stress: 25 ksi  
Test load: 7,000 lbs.  
Load ratio: (R) = 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophore (36 Kip)

2024  
C/W Open  
25 ksi

Specimen No. R-623078	Hole No.	Hole Diameter (inches)			Hole Finish (RMR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-15	1	.3555	.3665	.3735	35	20	30	.0185	.0110	975	 C/W
	2	.3552	.3668	.3735	-	-	-	.0188	.0116		
-16	1	.3552	.3665	.3735	35	20	30	.0188	.0113	366	 C/W
	2	.3555	.3665	.3735	-	-	-	.0185	.0110		
-22	1	.3555	.3670	.3730	40	20	30	.0185	.0115	12,700	 No Failure
	2	.3555	.3670	.3730	-	-	-	.0185	.0115		

1. Taken at Minimum (midpoint)

# PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: 11A7  
 NOMINAL EXPANSION VALUE: 0.0185-0.020

## GENERAL TEST CONDITIONS

DATE: 2-9-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: 0.354"  
 Lubrication: Fel Pro 300 (on sleeve)




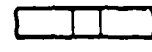
### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Drill, ream, CW & ream

### 4. Fatigue Conditions

Net stress: 35 ksi  
 Test load: 9,900 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

2024  
 C/W Open  
 35 ksi

Specimen No. R-623078	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-17	1	.3555	.3665	.3735	40	20	30	.0185	.0110	96	 C/W
	2	.3555	.3665	.3735	-	-	-	.0185	.0110		
-18	1	.3555	.3665	.3735	35	15	30	.0185	.0110	114	 C/W
	2	.3555	.3665	.3735	-	-	-	.0185	.0110		
											

1. Test Results (Materials) (continued)

# PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: II A 8

NOMINAL EXPANSION VALUE: 0.0181-0.020

## GENERAL TEST CONDITIONS

DATE: 2-9-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig 2  
Width: 1.50"  
Hole spacing: 1.50"  
Edge margin: 0.75"  
Material: 2024 T 851  
Material gauge: 0.250"  
Surface Treatment: Shot Peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.010"  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM- 12 -0-N  
CW Mandrel Taper: 0.045"/"  
CW Mandrel Major Dia.: 0.354"  
Lubrication: Fel Pro 300 (on sleeve)





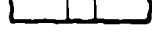
### 2. Hole Preparation

Nominal hole size: 3/8"  
Process: Drill, ream, CW & ream

### 4. Fatigue Conditions

Net stress: 40 ksi  
Test load: 11,400 lbs.  
Load ratio: (R) = 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophore (36 Kip)

2024  
C/W Open  
40 ksi

Specimen No. R-623078	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-19	1	.3555	.3665	.3735	40	20	30	.0185	.0110	35	 C/W
	2	.3555	.3665	.3735	-	-	-	.0185	.0110		
-20	1	.3560	.3665	.3735	40	20	30	.0180	.0105	38	 C/W
	2	.3555	.3665	.3735	-	-	-	.0185	.0110		
											

 Taken at Minimum (midpoint)

# PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: 11A9 (7175 T 736)

NOMINAL EXPANSION VALUE: \_\_\_\_\_

## GENERAL TEST CONDITIONS

DATE: 4-5-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 2  
Width: 1.50"  
Hole spacing: 1.50"  
Edge margin: 0.75"  
Material: 7175 T 736  
Material gauge: 0.250  
Surface Treatment: Shot Peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial  
Sleeve thickness: \_\_\_\_\_  
Sleeve orient: 0°  
CW Mn: 50-CBM -0-N  
CW: \_\_\_\_\_  
Major Dia.: \_\_\_\_\_  
Fin: Fel Pro 300 (on sleeve)

**NOT APPLICABLE**



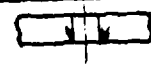
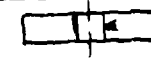
### 2. Hole Preparation

Nominal hole size: 3/8"  
Process: Ream Only

### 4. Fatigue Conditions

Net stress: 30 ksi  
Test load: 8,500 lbs.  
Load ratio: (R) 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophore (36 Kip)

7175  
Reamed Open  
30 ksi

Specimen No. R-623078	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-1	1	-	-	.3735	-	-	35	-	-	45	
	2	-	-	.3735	-	-	-	-	-	-	
-2	1	-	-	.3735	-	-	40	-	-	56	
	2	-	-	.3735	-	-	-	-	-	-	
-3	1	-	-	.3735	-	-	35	-	-	69	
	2	-	-	.3735	-	-	-	-	-	-	

1 - Taken at Minimum (midpoint)

# PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: II A 10 (7175 T 736)  
 NOMINAL EXPANSION VALUE: 0.019"

## GENERAL TEST CONDITIONS

DATE: 4-15-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 7175 T 736  
 Material gauge: 0.250  
 Surface Treatment: Shot Peen  
 Fastener: None

### 3. CW Process

Sleeve type: Axial Sn  
 Sleeve thickness:             
 Sleeve orientation:             
 CW Mandrel: CBM- -0-N  
 CW Mandrel Major Dia.:             
 CW Mandrel: Fel Pro 300 (on sleeve)

**NOT APPLICABLE**


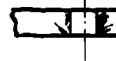
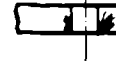

### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, C/W, Ream

### 4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,575 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

7175  
 C/W Open  
 30 ksi

Specimen No. R-623078	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
4	1	.3540	.3670	.3735	35	15	40	.0190	.0130	510	 C/W
	2	.3540	.3670	.3735	-	-	-	.0190	.0130		
-5	1	.3540	.3670	.3735	35	15	35	.0190	.0130	618	 C/W
	2	.3540	.3670	.3735	-	-	-	.0190	.0130		
-6	1	.3540	.3665	.3735	40	15	40	.0190	.0125	692	 C/W
	2	.3540	.3670	.3735	-	-	-	.0190	.0130		

1 - Taken at Minimum (midpoint)

# PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

Ti 6Al 5V annealed,  
honed open,  
65 ksi

TEST 2T1 SPECIMEN 623078 DATE 9/14/73

## SPECIMEN DESCRIPTION

Fig. 2  
Configuration Ti 6Al 4V (annealed)  
Material  
Width (in) 1.50  
Hole spacing (in) 1.50  
Edge margin (in) 0.75  
Material gauge (in) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS

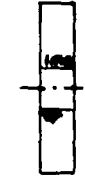

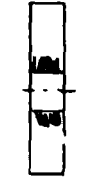
Interference  
Sleeve type  
Sleeve thickness (in)  
Sleeve orientation  
Mandrel material  
Mandrel taper (in/in)  
Mandrel max diameter (in)  
Lubrication

## HOLE PREPARATION

Nominal hole size (in) 3/8  
Process Drill, ream, hone  
FASTENER INSTALLATION  
Type  
Fit  
Torque (in lb)

## FATIGUE CONDITIONS

Max net stress (ksi) 65  
Max test load (kip) 19  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 36-kip Vibrophore

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After hone	Before coldwork	After coldwork	After hone	Actual	Retained	Diameter	Fit		
1	1		0.3755				30					41,000	
	2		0.3755										
	3												
	4												
2	1		0.3755				30					66,000	
	2		0.3755										
	3												
	4												
3	1		0.3755				35					58,000	
	2		0.3755										
	3												
	4												

Ti-6Al-4V,  
reamed open,  
60 ksi

TEST 2T2 SPECIMEN 623078 DATE 8/30/73

## CCLDWORK PROCESS

**Interference**

T: 6A1.4V (annealed)

i

1.50

Sleeve thickness (in)

1

**Stem orientation**

Edge margin (in)

Mandrel material

0.250

Mandrel taper (in /in)

## Surface treatment

Mandrel max diameter

## FATIGUE CONDITIONS

Nominal bolt size (in.)

0.375

### Process:

## Ream

Sleeve thickness (in)

### Stem orientation

Mandrel material

## FASTENER INSTALLATION

Mandrel taper (in/in)

Type

**Mandrel max diameter**

F.11

**Lubrication.**

Torque (in lb)

## FATIGUE CONDITIONS

Max net stress (ksi)	60
----------------------	----

Max test load (kN)	18.4
--------------------	------

Load ratio (R)  $\dots \dots \frac{0.1}{1}$

Test frequency . . . 4000 cpm

## Test laboratory

Test engineer . . . D. Reese

Test machine

[illegible]

# PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

Ti 6Al-4V,  
reamed open  
64 ksi

TEST 2T3 SPECIMEN 623078 DATE 8/30/73

## SPECIMEN DESCRIPTION

Configuration Fig. 2  
Material Ti-6Al-4V (annealed)  
Width (in) 1.50  
Hole spacing (in) 1.50  
Edge margin (in) 0.75  
Material gage (in) 0.250  
Surface treatment: Shot peen

## COLDWORK PROCESS

Interference  
Sleeve type  
Sleeve thickness (in)  
Sleeve orientation  
Mandrel material  
Mandrel taper (in/in)  
Mandrel max diameter (in)  
Lubrication

## HOLE PREPARATION






Nominal hole size (in) 0.375  
Process Ream

## FASTENER INSTALLATION

Type  
Fit  
Torque (in lb)

## FATIGUE CONDITIONS

Max net stress (ksi) 65  
Max test load (kip) 19.2  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 36 kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
6	1			0.3755			30					41,000	
	2			0.3755			-						
	3												
	4												
7	1			0.3755			25					39,000	
	2			0.3755			-						
	3												
	4												
	1												
	2												
	3												
	4												

## PHASE II—TASK 2—BASIC OPEN-HOLE VALUES

**T1-6A1-4V,  
reamed open,  
50 ksi**

TEST	SPECIMEN	DATE
2T4	623078	8/30/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference		Nominal hole size (in.)	0.375	Max. net stress (ksi)	50
Material	Ti-6Al-4V (annealed)	Sleeve type		Process	Ream	Max. test load (kip)	14.3
Width (in.)	1.50	Sleeve thickness (in.)				Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation				Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material		FASTENER INSTALLATION			
Material gauge (in.)	0.250	Mandrel taper (in./in.)		Type		Test laboratory	Materials
Surface treatment	Shot peen	Mandrel max. diameter (in.)		Fit		Test engineer	D. Reese
		Lubrication		Torque (in.-lb)		Test machine	36-kip vibraphore

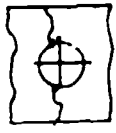
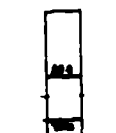
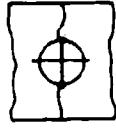
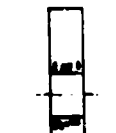
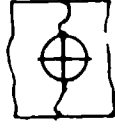
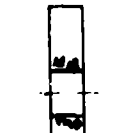
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# PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

Ti 6Al 4V,  
reamed open,  
55 ksi

TEST 215 SPECIMEN 623078 DATE 8/30/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference		Nominal hole size (in.)	0.375	Max net stress (ksi)	55
Material	Ti 6Al 4V (annealed)	Sleeve type		Process	Ream	Max test load (kip)	16
Width (in.)	1.50	Sleeve thickness (in.)				Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation				Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material		FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)		Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)		Fit		Test machine	36 kip Vibraphore
		Lubrication		Torque (in. lb)			

Specimen dash no.	Hole no.	Hole diameter (in.)			Hole finish (RHRI)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
8	1			0.3755			30					42,000	
	2			0.3755			-						
	3												
	4												
11	1			0.3755			25					57,000	
	2			0.3755			-						
	3												
	4												
12	1			0.3755			25					117,000	
	2			0.3755			-						
	3												
	4												

## PHASE II—TASK 2—BASIC OPEN-HOLE VALUES

T1-6A1-4V  
C&W open.  
60 ksi

TEST	2T6	SPECIMEN	623078	DATE	8/30/73
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## SPECIMEN DESCRIPTION

**Fig. 2**

Ti-6Al-4V (annealed)

159

0.250

Short pe

## COLDWORK PROCESS

Interference (in.)

Sieve type

Sleeve thickness (in)

## Steve Orientation

## Manurel material

Mandrel taper (in/in)

Handel max diameter (in )

Lubricants • C. J. P. Orr

## HOLE PREPARATION

0.019

Split

0.010

0

AlSi19260 steel

0.045

0.353

Fel Pro 300

## FATIGUE CONDITIONS

3

Mr. Tolson (11-2)

Load ratio (B)

Test frequency

Test laboratory

**Test engineer**

**Test machine**

## FASTENER INSTALLATION

0.045

0.353

Torque (in. - lb)

[illegible]

# PHASE II-TASK2 - BASIC OPEN-HOLE VALUES

Ti-6Al-4V,  
C&W open,  
50 ksi

TEST 2T7 SPECIMEN 623078 DATE 8/30/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference (in.)	0.019	Nominal hole size (in.)	0.375	Max net stress (ksi)	50
Material	Ti-6Al-4V (annealed)	Sleeve type	Split	Process	Ream, C/W, ream	Max test load (kip)	14.4
Width (in.)	1.50	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation	0°			Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material gage (in.)	0.250	Mandrel taper (in/in)	0.045	Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.353	Fit		Test machine	36 kip Vibrashore
		Lubrication	Fel Pro 300	Torque (in. lb)			

Specimen dash no.	Hole no.	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
.15	1	0.3545	0.3635	0.3555	30	18	20	0.0185	0.0090			1,576,000	
	2	0.3545	0.3635	0.3755	-	-	-	0.0185	0.0090				
	3												
	4												
16	1	0.3545	0.3630	0.3755	25	15	25	0.0185	0.0085			6,868,000	
	2	0.3545	0.3630	0.3755	-	-	-	0.0185	0.0085				
	3												
	4												
.17	1	0.3545	0.3635	0.3755	25	12	25	0.0185	0.0090			-	
	2	0.3545	0.3635	0.3755				0.0185	0.0090				
	3												
	4												

Ti-6Al-4V,  
C/W open,  
70 ksi

TEST 2T8 SPECIMEN 623078 DATE 8/30/73

## SPECIMEN DESCRIPTION

**Fig. 2**

Configuration

width (in)

1.50

Wavelength (nm)

1.50

Edge margin (in )

0.75

0.250

Surface treatment      Shot peen

## COLDWORK PROCESS

## Interference

Slieve Donard

Sleeve thickness (in.)

**Classification**

leiamen jospoey

Student name: \_\_\_\_\_

**Molecular mass determination**

## HOIF PREPARATION

Nominal hole size (in)

**Process**

## FASTENER INSTALLATION

Type

3

Total (no. lbs)

## FATIGUE CONDITIONS

Max net stress (ksi)

Max test load (kN)

$$\text{Load ratio (R)} = \frac{0.1}{0.1}$$

Test frequency 4000 cpm

## Materials

**Test engineer**  
**O. Reese**

Test machine

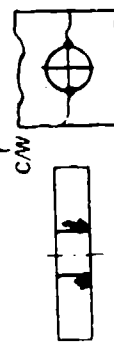
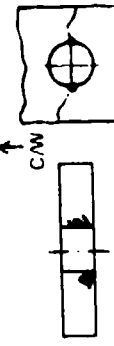
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# PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

Ti-6Al-4V,  
C/W open,  
65 ksi

TEST 2T9 SPECIMEN 623078 DATE 8/30/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference (in.)	0.019	Nominal hole size (in.)	0.375	Max net stress (ksi)	65
Material	Ti-6Al-4V (annealed)	Sleeve type	Split	Process	Ream, C/W, ream	Max test load (kip)	18.7
Width (in.)	1.50	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation	0			Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)	0.045	Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.353	Fit		Test machine	100 kip Vibraphore
		Lubrication	Fel Pro 300	Torque (in. lb)			

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHRI)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
20	1	0.3545	0.3640	0.3755	25	12	25	0.0185	0.0095			88,000	
	2	0.3545	0.3635	0.3755	-	-	-	0.0185	0.0090				
	3												
	4												
21	1	0.3545	0.3640	0.3755	30	15	25	0.0185	0.0095			104,000	
	2	0.3545	0.3625	0.3755	-	-	-	0.0185	0.0090				
	3												
	4												
	1												
	2												
	3												
	4												

# PHASE II-TASK 2- BASIC OPEN-HOLE VALUES

Ti-6Al-4V sta.  
reamed open.  
70 ksi

TEST 2T10 SPECIMEN 623078 DATE 9/11/73

## SPECIMEN DESCRIPTION

Configuration Fig. 2  
Material Ti-6Al-4V (sta)  
Width (in) 1.50  
Hole spacing (in) 1.50  
Edge margin (in) 0.75  
Material gauge (in) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS

Interference  
Sleeve type  
Sleeve thickness (in)  
Sleeve orientation  
Mandrel material  
Mandrel taper (in/in)  
Mandrel max diameter (in)  
Cutting tool

## HOLE PREPARATION

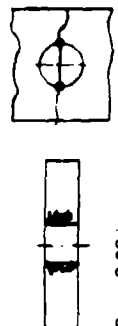
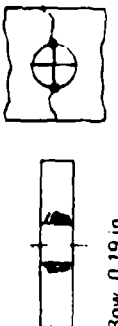






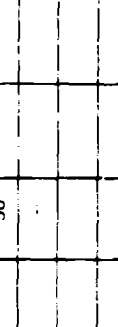

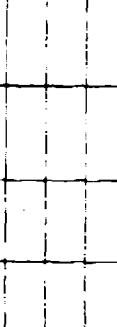

Nominal hole size (in) 3/8  
Process Drill and ream

## FATIGUE CONDITIONS

Max net stress (ksi) 70  
Max test load (kip) 20.3  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D Reese  
Test machine 100 kip Vibraphore

## FASTENER INSTALLATION

Type  
Fit  
Torque (in lb)


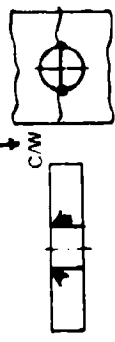
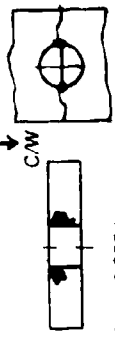
Specimen flush no	Hole no	Hole diameter (in)				Hole finish (RHRI)				Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit				
-1 sta	1		0.3755				30							26,000	
	2		0.3755												
	3														
	4														
-2 sta	1		0.3755				35							30,000	
	2		0.3755												
	3														
	4														
-3 sta	1		0.3755				30							36,000	
	2		0.3755												
	3														
	4														

# PHASE II - TASK 2 - BASIC OPEN HOLE VALUES

Ti-6Al-4V, sta.  
C/W open,  
70 ksi

TEST 2T11 SPECIMEN 623078 DATE 9/12/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference (in.)	0.019	Nominal hole size (in.)	3/8	Max net stress (ksi)	70
Material	Ti-6Al-4V (sta)	Sieve type	Split	Process	Drill, ream, C/W	Max test load (kip)	20.5
Width (in.)	1.50	Sieve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sieve orientation	0			Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)	0.045	Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.353	Fit		Test machine	100-kip Vibraphore
		Lubrication		Torque (in. lb)			

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHr)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
4 sta	1	0.3545	0.3630	0.3740	35	20	35	0.0085	0.0085			81,000	
	2	0.3545	0.3630	0.3740	-	-	-	0.0085	0.0085				
	3												
	4												
5 sta	1	0.3545	0.3630	0.3740	40	20	30	0.0185	0.0085			85,000	
	2	0.3545	0.3630	0.3740	-	-	-	0.0185	0.0085				
	3												
	4												
6 sta	1	0.3545	0.3630	0.3740	40	20	30	0.0185	0.0085			51,000	
	2	0.3545	0.3630	0.3740	-	-	-	0.0185	0.0085				
	3												
	4												

# PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

Ti 6Al-4V, S<sup>100</sup>  
reamed open  
70 ksi

TEST 2T12 SPECIMEN 623078 DATE 9/11/73

## SPECIMEN DESCRIPTION

Fig. 2  
Ti-6Al-4V (stoa)  
1.50  
1.50  
0.75  
0.750  
Shot peen

## COLDWORK PROCESS

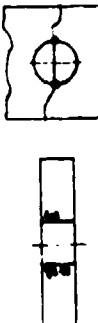





Interference  
Sleeve type  
Sleeve thickness (in.)  
Sleeve orientation  
Mandrel material  
Mandrel taper (in./in.)  
Mandrel max diameter (in.)  
Lubrication

## HOLE PREPARATION

Nominal hole size (in.)  
Process  
Drill and ream  
3.8  
Drill and ream

## FATIGUE CONDITIONS

Max net stress (ksi)  
Max test load (kip)  
Load ratio (R)  
Test frequency  
Test laboratory  
Test engineer  
Test machine  
70  
20  
0.1  
400 cpm  
Materials  
D. Reese  
100 kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (HR)				Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit			
1 stoa	1			0.3755				25					30,000	
	2			0.3755			-							
	3													
	4													
2 stoa	1			0.3755				40					32,000	
	2			0.3755			-							
	3													
	4													
3 stoa	1			0.3755				35					33,000	
	2			0.3755										
	3													
	4													

# PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

Ti 6Al 4V stoa,  
C/W open,  
70 ksi

TEST 2T13 SPECIMEN 623078 DATE 9/12/73

## SPECIMEN DESCRIPTION

Fig. 2  
Configuration  
Material  
Width (in.)  
Hole spacing (in.)  
Edge margin (in.)  
Material gage (in.)  
Surface treatment

## COLDWORK PROCESS

Interference (in.)  
Sleeve type  
Sleeve thickness (in.)  
Sleeve orientation  
Mandrel material  
Mandrel taper (in./in.)  
Mandrel max diameter (in.)  
Lubrication

## HOLE PREPARATION


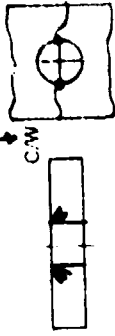
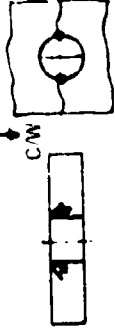
Nominal hole size (in.)  
Process  
Type  
Fit  
Torque (in. lb)

## FASTENER INSTALLATION

AISI 9260 steel  
Type  
Fit  
Torque (in. lb)

## FATIGUE CONDITIONS

Max net stress (ksi)  
Max test load (kip)  
Load ratio (R)  
Test frequency  
Test laboratory  
Test engineer  
Test machine

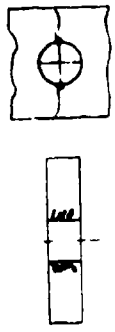
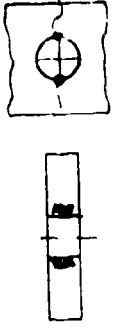
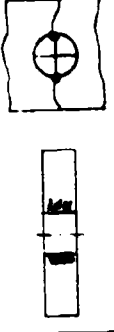
Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (IRHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
4 Stoa	1	0.3545	0.3640	0.3740	45	20	35	0.0185	0.0095			70,000	
	2	0.3540	0.3640	0.3740				0.0185	0.0095				
	3												
	4												
5 Stoa	1	0.3545	0.3640	0.3740	40	10	35	0.0185	0.0095			38,000	
	2	0.3545	0.3640	0.3740				0.0185	0.0095				
	3												
	4												
6 Stoa	1	0.3545	0.3640	0.3740	35	15	35	0.0185	0.0095			58,000	
	2	0.3545	0.3640	0.3735				0.0185	0.0095				
	3												
	4												

Ti-6Al-6V-2Sn,  
reamed open.  
70 ksi

PHASE II-TASK 2 - BASIC OPEN-HOLE DATA

TEST 2T14 SPECIMEN 623078 DATE 10/1/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference		Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti-6Al-6V-2Sn (annealed)	Sleeve type		Process	Ream	Max test load (kip)	20.3
Width (in.)	1.50	Sleeve thickness (in.)				Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation				Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material		FASTENER INSTALLATION			
Material gage (in.)	0.250	Mandrel taper (in/in)		Type		Test laboratory	Materials
Surface treatment	Shot peen	Mandrel max diameter (in.)		Fit		Test engineer	D. Reese
		Lubrication		Torque (in. lb)		Test machine	36 kip Vibraphore

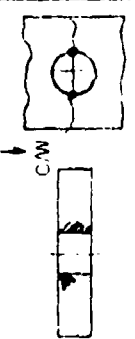
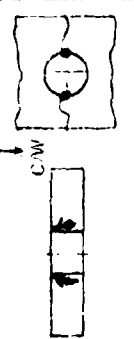
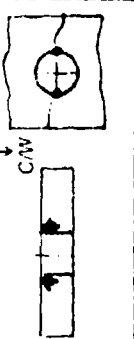
Spec. ident. no.	Hole no.	Hole diameter (in.)			Hole finish (RHR)			Collwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before collwork	After collwork	After ream	Before collwork	After collwork	After ream	Actual	Retained	Diameter	Fit		
1-662	1			0.3750			30					51,000	
	2			0.3750			25						
	3												
	4												
2-662	1			0.3750			15					35,000	
	2			0.3750			15						
	3												
	4												
3-662	1			0.3750			15					28,000	
	2			0.3750			15						
	3												
	4												

# PHASE II TASK 2- BASIC OPEN-HOLD DATA

Ti-6Al-6V-2Sn,  
C/W open,  
70 ksi

TEST 2715 SPECIMEN 623078 DATE 10/11/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference (in)	0.019	Nominal hole size (in)	0.375	Max. net stress (ksi)	70
Material	Ti-6Al-6V-2Sn (annealed)	Sleeve type	Split	Process	Ream: C/W, ream	Max. test load (kip)	20.3
Width (in)	1.50	Sleeve thickness (in)	0.010			Load ratio (R)	0.1
Hole spacing (in)	1.50	Sleeve orientation	0			Test frequency	4000 cpm
Edge margin (in)	0.75	Mandrel material	AST 9260 steel	FASTENER INSTALLATION			
Material gage (in)	0.250	Mandrel taper (in/in)	0.045	Type		Test laboratory	Materials
Surface treatment	Shot peen	Mandrel max diameter (in)	0.353	Fit		Test engineer	D. Reese
		Lubricant	Fel Pro 300	Torque (in. lbs)		Test machine	36-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in)				Hole finish (RHR)		Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	After coldwork	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
4-662	1	0.3540	0.3620	0.3750	35	20	20	0.0190	0.0080			50,000	
	2	0.3540	0.3620	0.3750				0.0190	0.0080				
	3												
	4												
5-662	1	0.3540	0.3620	0.3750	35	20	20	0.0190	0.0080			70,000	
	2	0.3540	0.3630	0.3750				0.0190	0.0090				
	3												
	4												
6-662	1	0.3540	0.3620	0.3750	35	20	25	0.0190	0.0080			79,000	
	2	0.3540	0.3620	0.3750				0.0190	0.0080				
	3												
	4												

Ti-6Al-6V-2Sn sta.  
reamed open.  
70 ksi

TEST: 2T16 SPECIMEN 623078 DATE 10/1/73

## SPECIMEN DESCRIPTION

**Fig. 2**

Ti-6Al-6V-2Sn (sta)

1.50

1.50

0.79

0.25

540

## COLDWORK PROCESS

**Interference**

Slieve Donard

Steve (The King) (27)

**Manuscript material**

Mineral 2000 1.0 1.0

**Minister of Justice**

1. *Introduction*

## HOLE PREPARATION

— 5 —

1

## FASTENER INSTALLATION

1

3

3

## FATIGUE CONDITIONS

70

20

0.1

400

Ma

0

36.

[illegible]

# PHASE II - TASK 2 - BASIC OPEN-HOLE DATA

Ti-6Al-6V-2Sn sta.  
C/W open.  
70 ksi

TEST: 2117 SPECIMEN: 623078 DATE: 10/11/73

**FATIGUE CONDITIONS**

Max net stress (ksi) 70

Max test load (kip) 20

Load ratio (R) 0.1

Test frequency 4000 cpm

Test laboratory Materials

Test engineer D. Reese

Test machine 36-kip Vibraphore

**COLDWORK PROCESS**

Interference (in.) 0.019

Sleeve type Split

Sleeve thickness (in.) 0.010

Sleeve orientation 0

Manifold material ANSI 9260 steel

Manifold taper (in/in) 0.045

Manifold max diameter (in.) 0.353

Lubrication Fel Pro 300

**HOLE PREPARATION**

Nominal hole size (in.) 0.375

Process Ream, C/W, ream

**FASTENER INSTALLATION**

Type

Fit

Torque (in lb)

## SPECIMEN DESCRIPTION

Fig. 2

Configuration Ti-6Al-6V-2Sn (sta)

Material Ti-6Al-6V-2Sn (sta)

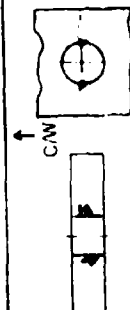
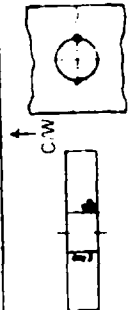
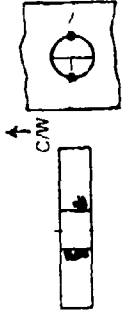
Width (in.) 1.50

Hole spacing (in.) 1.50

Edge margin (in.) 0.75

Material gauge (in.) 0.250

Surface treatment Shot peen

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHRI)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
4 662 sta	1	0.3540	0.3625	0.3745	35	20	25	0.0190	0.0085			76,000	
	2	0.3540	0.3625	0.3745			-	0.0190	0.0085				
	3												
	4												
5 662 sta	1	0.3540	0.3620	0.3745	35	20	25	0.0190	0.0080			94,000	
	2	0.3540	0.3625	0.3745			-	0.0190	0.0085				
	3												
	4												
6 662 sta	1	0.3540	0.3625	0.3745	35	20	30	0.0190	0.0085			72,000	
	2	0.3540	0.3630	0.3745			-	0.0190	0.0090				
	3												
	4												

# PHASE II - TASK 2 - BASIC OPEN-HOLE DATA

Ti-6Al-6V-2Sn stoa,  
reamed open,  
70 ksi

TEST: 2T18 SPECIMEN 623078 DATE 10/1/73

## SPECIMEN DESCRIPTION

Fig. 2  
Configuration Ti-6Al-6V-2Sn (stoa)  
Material 1.50  
Width (in.) 1.50  
Hole spacing (in.) 0.75  
Edge margin (in.) 0.250  
Material grade (in.) Shot peen  
Surface treatment

## COLDWORK PROCESS

Interference  
Sleeve type  
Sleeve thickness (in.)  
Sleeve orientation  
Mandrel material  
Mandrel taper (in./in.)  
Mandrel max diameter (in.)  
Lubrication

## HOLE PREPARATION

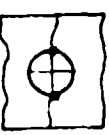

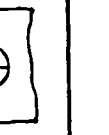
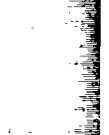
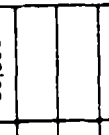
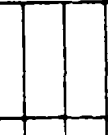

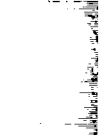
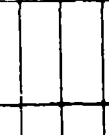
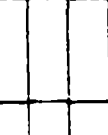
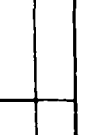

Nominal hole size (in.) 0.375  
Process Ream

## FASTENER INSTALLATION

Type  
Fit  
Torque (in. lb)

## FATIGUE CONDITIONS

Max net stress (ksi) 70  
Max test load (kip) 20  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 36-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
1 662 stoa	1		0.3750				15					38,000	
	2												
	3												
	4												
2 662 stoa	1		0.3750				15					38,000	
	2												
	3												
	4												
3 662 stoa	1		0.3750				15					30,000	
	2												
	3												
	4												

# PHASE II - TASK 2 - BASIC OPEN-HOLE DATA

Ti-6Al-6V-2Sn sto. a.  
C/W open.  
70 ksi

TEST 2T19 SPECIMEN 623078 DATE 10/11/73

FATIGUE CONDITIONS

Max net stress (ksi) 70

Max test load (kip) 20

Load ratio (R) 0.1

Test frequency 4000 cpm

Test laboratory Materials

Test engineer D. Reese

Test machine 36-kip Vibraphore

HOLE PREPARATION

Nominal hole size (in.) 0.375

Process Ream, C/W, ream

## COLDWORK PROCESS

Interference (in.) 0.019

Sleeve type Split

Sleeve thickness (in.) 0.010

Sleeve orientation 0

Mandrel material AISI 9260 steel

Mandrel taper (in/in) 0.045

Mandrel max diameter (in.) 0.353

Lubrication Fel Pro 300

## SPECIMEN DESCRIPTION

Fig. 2

Configuration Ti 6Al-6V-2Sn (sto. a.)

Material 1.50

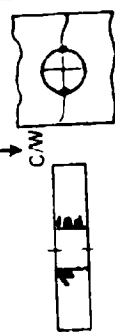
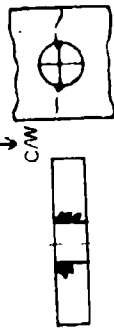
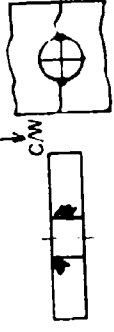
Width (in.) 1.50

Hole spacing (in.) 0.75

Edge margin (in.) 0.250

Material grade (in.) Shot peen

Surface treatment

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RA/R)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	F.t		
4.662 sto. a.	1	0.3540	0.3620	0.3745	35	20		0.0190	0.0080			67,000	
	2	0.3540	0.3625	0.3745	-	-		0.0190	0.0085				
	3												
	4												
5.662 sto. a.	1	0.3540	0.3620	0.3745	35	20		0.0190	0.0080			48,000	
	2	0.3540	0.3620	0.3745	-	-		0.0190	0.0080				
	3												
	4												
6.662 sto. a.	1	0.3540	0.3625	0.3750	35	20		0.0190	0.0085			55,000	
	2	0.3540	0.3625	0.3750	-	-		0.0190	0.0085				
	3												
	4												

# PHASE II-TASK 2 - BASIC OPEN-HOLE DATA

Ti-6Al-5V,  
C/W 0.015  
3/4 in. Ø, 70 Ksi

TEST 2T20 SPECIMEN 623078 DATE 10/24/73

## SPECIMEN DESCRIPTION

Configuration Fig. 2  
Material Ti-6Al-4V (annealed)  
Width (in.) 3.00  
Hole spacing (in.) 3.00  
Edge margin (in.) 1.50  
Material gauge (in.) 0.375  
Surface treatment Shot peen

## COLLWORK PROCESS

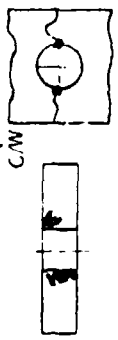
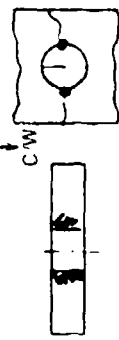
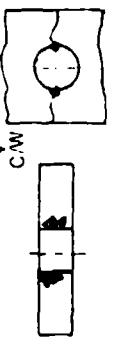
Interference (in.) 0.030  
Sleeve type Split  
Sleeve thickness (in.) 0.015  
Sleeve orientation 0  
Mandrel material AISI 9260  
Mandrel taper (in./in.) 0.045  
Mandrel max diameter (in.) 0.7140  
Cutting speed FeI Pro 300

## HOLE PREPARATION

Nominal hole size (in.) 0.750  
Process Ream, C/W, ream

## FATIGUE CONDITIONS

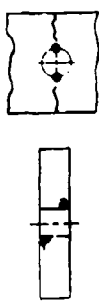
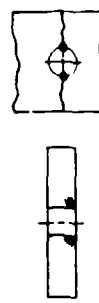
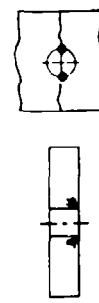
Max net stress (ksi) 70  
Max test load (kip) 59  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 100-kip Vibraphore

Specimen dash no.	Hole no.	Hole diameter (in.)			Hole finish (RHR)			Collwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before collwork	After collwork	After ream	Before collwork	After collwork	After ream	Actual	Retained	Diameter	Fit		
25	1	0.715	0.7270	0.7510	25	15	25	0.027	0.0120			86,000	
	2	0.715	0.7270	0.7515	-	-	-	0.029	0.0120				
	3												
	4												
26	1	0.715	0.7270	0.7515	30	20	30	0.029	0.0120			54,000	
	2	0.715	0.7270	0.7505	-	-	-	0.029	0.0120				
	3												
	4												
27	1	0.715	0.7265	0.7505	25	15	35	0.029	0.0115			61,000	
	2	0.715	0.7265	0.7575	-	-	-	0.029	0.0115				
	3												
	4												

PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES  
300 M, Honed, Open

TEST 2S1 SPECIMEN 623078 DATE 7/19/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference	—	Nominal hole size (in.)	3/8	Max. net stress (ksi)	105
Material	300 M steel (270-300 ksi)	Sieve type	—	Process	Drill, ream, and hone	Max. test load (kip)	29.4
Width (in.)	1.50	Sieve thickness (in.)	—			Load ratio (R)	0.1
Hole spacing	1.50	Sieve orientation	—			Test frequency	4200 cpm
Edge margin (in.)	0.75	Mandrel material	—	FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)	—	Type	—	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	—	Fit	—	Test machine	36-kip Vibraphore
		Lubrication	—	Torque (in. lb)	—		

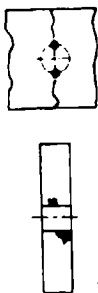
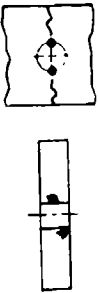
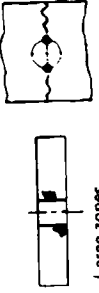
Specimen fish no.	Hole diameter (in.)				Hole finish (HRH)				Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
	Before coldwork	After coldwork	After ream	After ream	Before coldwork	After coldwork	After ream	After ream	Actual	Retained	Diameter	Fit		
-1	1			0.3804									43,000	 Large zones
	2			0.3804										
	3													
	4													
-2	1			0.3803									54,000	 Large zones
	2			0.3803										
	3													
	4													
-3	1			0.3803									42,000	 Large zones
	2			0.3803										
	3													
	4													

# PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

300 M, Reamed, Open, 105 KSI

TEST 2S2 SPECIMEN 623028 DATE 2/10/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig 2	Interference		Nominal hole size (in)	3/8	Max net stress (ksi)	105
Material	300 M steel (270-300 ksi)	Sleeve type		Process	Drill and ream	Max test load (kip)	30
Width (in)	1.50	Sleeve thickness (in)				Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation				Test frequency	7000 cpm
Edge margin (in)	0.75	Mandrel material		FASTENER INSTALLATION		Test laboratory	Materials
Material grade (in)	0.250	Mandrel taper (in/in)		Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in)		Fit		Test machine	36 kip Vibtrophore
		Lubrication		Torque (in lb)			

Specimen dash no	Hole no	Hole diameter (in)			Hole finish (RHR)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
-4	1		0.375				15					139,000	 Large zones
	2		0.375										
	3												
	4												
-5	1		0.375				20					103,000	 Large zones
	2		0.375										
	3												
	4												
-6	1		0.375				15					75,000	 Large zones
	2		0.375										
	3												
	4												

# PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

300 M. Reamed, Open, 110 KSI

TEST 253 SPECIMEN 623078 DATE 7/10/73

## SPECIMEN DESCRIPTION

Fig. 2  
 Configuration 300 M steel (270-300 ksi)  
 Material 300 M steel (270-300 ksi)  
 Width (in) 1.50  
 Hole spacing 1.50  
 Edge margin (in) 0.75  
 Material gauge (in) 0.250  
 Surface treatment Shot peen

## COLDWORK PROCESS

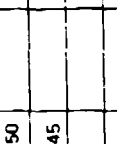
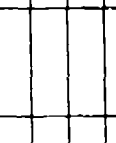
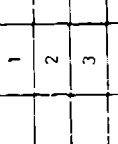
Interference —  
 Shear type —  
 Sleeve thickness (in) —  
 Shear orientation —  
 Mandrel material —  
 Mandrel taper (in/in) —  
 Mandrel max diameter (in) —  
 Lubrication —

## HOLE PREPARATION

Nominal hole size (in) 3/8  
 Process Drill and ream  
 FASTENER INSTALLATION  
 Type —  
 Fit —  
 Torque (in lb) —

## FATIGUE CONDITIONS

Max. net stress (ksi) 110  
 Max. test load (kip) 31  
 Load ratio (R) 0.1  
 Test frequency 7000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36-kip Vibraphore

Specimen dash no.	Hole no.	Hole diameter (in.)			Hole finish (HR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
-7	1			0.3750			20					48,000	 Large zones
	2			0.3745			—						
	3												
	4												
-8	1			0.3745			20					60,000	 Large zones
	2			0.3745			—						
	3												
	4												
	1												 Large zones
	2												
	3												
	4												

# PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

300 M. Reamed, Open, 120 KSI

TEST 2S4 SPECIMEN 623078 DATE 7/10/73

## SPECIMEN DESCRIPTION

Fig. 2

Configuration 300 M steel (270-300 ksi)  
Material 300 M steel (270-300 ksi)  
Width (in) 1.50  
Hole spacing 1.50  
Edge margin (in) 0.75  
Material gap (in) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS

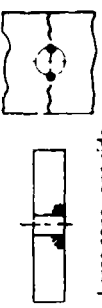
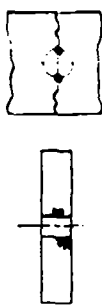
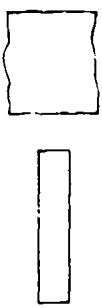
Interference —  
Sleeve type —  
Sleeve thickness (in) —  
Sleeve orientation —  
Mandrel material —  
Mandrel taper (in/in) —  
Mandrel max diameter (in) —  
Lubrication —

## HOLE PREPARATION

Nominal hole size (in) 3/8  
Process Drill and ream  
FASTENER INSTALLATION  
Type —  
Fit —  
Torque (in lb) —

## FATIGUE CONDITIONS

Max out stress (ksi) 120  
Max test load (kip) 37  
Load ratio (R) 0.1  
Test frequency 7000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 36 kip Vibraphore

Specimen group no	Hole no	Hole diameter (in)			Hole finish (THRI)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
-9	1		0.3745				20					32,000	 Large zone—one side
	2		0.3745				—						
	3												
	4												
-10	1		0.3745				20					49,000	 Large zone—one side
	2		0.3745				—						
	3												
	4												
	1												 Large zone—one side
	2												
	3												
	4												

# PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

300 M, Reamed, Open, 100 KSI

TEST: 255 SPEC. MEN: 623078 DATE: 7/10/73

## SPECIMEN DESCRIPTION

Fig. 2

Configuration	Fig. 2
Material	300 M steel (270-300 ksi)
Width (in.)	1.50
Hole spacing	1.50
Edge margin (in.)	0.75
Material type (in.)	0.250
Surface treatment	Shot peen

## COLDWORK PREP. CS





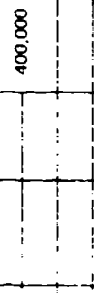
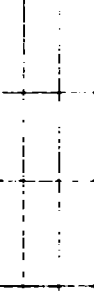

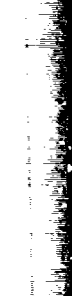
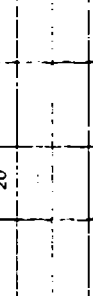
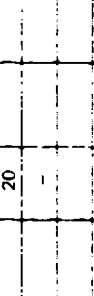
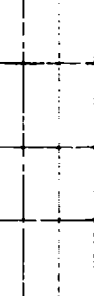

Interference	Process
Sleeve type	Drill and ream
Sleeve thickness (in.)	
Sleeve orientation	
Manifed material	
Manifed taper (in./in.)	Type
Manifed max diameter (in.)	Fat
Lubrication	Torque (in. lb)

## HOLE PREPARATION

Nominal hole size (in.)	Drill and ream
Process	
Type	
Fat	
Torque (in. lb)	

## FATIGUE CONDITIONS

Max. net stress (ksi)	100
Max. test load (kips)	28
Load ratio (R)	0.1
Test frequency	7000 cpm
Test laboratory	Materials
Test equipment	D. Reese
Test machine	36 kip Vibrashore

Specimen load no.	Hole no.	Hole diameter (in.)			Hole finish (IR40)			Coldwork exposure (in.)			Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	After coldwork	Before coldwork	After coldwork	After ream	Actual	Exposure	Exposure	Thread	P.T.		
11	1		0.3745				20						113,000	
	2		0.3745											
	3													
	4													
12	1		0.3745				20						400,000	
	2		0.3745											
	3													
	4													
	1													
	2													
	3													
	4													

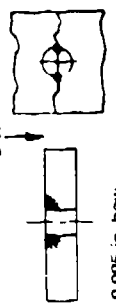
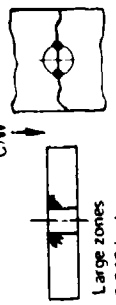
# PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

300 M, C/W, Open, 100 KSI

TEST 256 SPECIMEN 623078 DATE 7/26/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig 2	Interference (in.)	0.023 / 0.024	Nominal hole size (in.)	3/8	Max test stress (ksi)	100
Material	300 M steel (270-300 ksi)	Stress type	Push (no sleeve)	Process	Ream, C/W, Ream	Max test load (kip)	28.2
Width (in.)	1.50	Sleeve thickness (in.)	-			Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation	-			Test frequency	4200 cpm
Edge radius (in.)	0.75	Mandrel material	Carbide (BAC 5972)	FASTENER INSTALLATION		Test laboratory	Materials
Material grade (in.)	0.250	Mandrel taper (in/in)	0.045	Type	-	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.358	Fit	-	Test machine	100 kip Vibraphore
Lubrication		Fel Pro 300 in hole and on mandrel		Torque (in lbf)	-		

Note: Spiral reamer marks in holes from withdrawal; coldworked holes more difficult to ream

Specimen dash no.	Hole no.	Hole diameter (in.)			Hole finish (RH/R)			Coldwork extension (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
-13	1	0.3335	0.3510	0.3765	20	5	20	0.0245	0.0175			99,000	
	2	0.3335	0.3515	0.3745	-	-	-	0.0245	0.0180				
	3												
	4												
-14	1	0.3335	0.3510	0.3725	20	5	25	0.0245	0.0175			132,000	
	2	0.3335	0.3510	0.3740	-	-	-	0.0245	0.0175				
	3												
	4												
	1												
	2												
	3												
	4												

<sup>a</sup> Taken at minimum (midpoint)

<sup>b</sup> Step in hole where reamer failed, did not fail at step or stepped hole

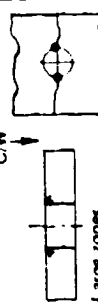
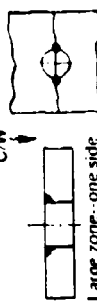
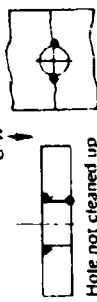
# PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

300 M. C/W. Open. 105 KSI

TEST 257 SPECIMEN 623078 DATE 7/27/72

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig 2	Interference (in.)	0.0245	Nominal hole size (in.)	3/8	Max net stress (ksi)	105
Material	300 M steel (270-300 ksi)	Stress type	Push (no sleeve)	Process	Ream. C/W. ream	Max test load (kips)	29.3
Width (in.)	1.50	Sleeve thickness (in.)	-			Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation	-			Test frequency	4200 cpm
Edge margin (in.)	0.75	Mandrel material	Carbide (BAC 5972)	FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)	0.045	Type	-	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max. diameter (in.)	0.358	Fit	-	Test machine	100 kip Vibration
		Lubrication	Fel Pro 300 in hole and on mandrel	Torque (in. ft)	-		

Note: Spiral reamer marks in holes from withdrawal; coldworked holes more difficult to ream.

Specimen dash no.	Hole no.	Hole diameter (in.)				Hole finish (RH)				Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork (al)	After ream	After coldwork	Before coldwork	After coldwork	Actual	Retained (al)			Diameter	Fit		
15	1	0.3335	0.3520	0.3745	15	5	20	0.0245	0.0185					54,000	
	2	0.3335	0.3525	0.3740	-	-	-	0.0245	0.0190						
	3														
	4														
16	1	0.3335	0.3515	0.3740	20	5	20	0.0245	0.0180					72,000	
	2	0.3335	0.3515	0.3740	-	-	-	0.0245	0.0180						
	3														
	4														
17	1	0.3335	0.3510	0.3740	20	5	20	0.0245	0.0175					71,000	
	2	0.3335	0.3510	0.3740	-	-	-	0.0245	0.0175						
	3														
	4														

<sup>a</sup>Taken at minimum (midpoint)

PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

300 M, C/W, Open, 110 KSI

TEST 258 SPECIMEN 623078 DATE 7/27/73

SPECIMEN DESCRIPTION				COLDWORK PROCESS				HOLE PREPARATION				FATIGUE CONDITIONS			
Fig. 2				Interference (in.)				Nominal hole size (in.)				Max net stress (ksi)			
Material 300 M steel (270-300 ksi)				Sleeve type				Process				Max test load (kip)			
Width (in.) 1.50				Sleeve thickness (in.)				Push (no sleeve)				Load ratio (R)			
Hole spacing 1.50				Sleeve orientation				Fastener (BAC 5972)				Test frequency			
Edge margin (in.) 0.75				Mandrel material				Carbide (BAC 5972)				Test delay			
Material type (in.) 0.250				Mandrel taper (in/in)				Type				Test engineer			
Surface treatment				Mandrel max diameter (in.)				F <sub>1</sub>				Test machine			
				Lubrication				Fat Pro 300 in hole and on mandrel							
								Torque (in. lb)							

Note: Spiral reamer marks in holes from withdrawal; coldworked holes more difficult to ream.

Specimen dash no	Hole no	Hole diameter (in.)				Hole finish (HR)				Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork (a)	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	F <sub>1</sub>				
-18	1	0.3335	0.3515	0.3745	20	5	--	0.0245	0.0180					41,000	C/W Large zones 0.078 in. bow
	2	0.3335	0.3515	0.3795	--	--	--	0.0245	0.0180						
	3														
	4														
-19	1	0.3335	0.3505	0.3745	20	5	20	0.0245	0.0170					62,000	C/W 0.070 in. bow
	2	0.3335	0.3505	0.3745	--	--	--	0.0245	0.0170						
	3														
	4														
	1														
	2														
	3														
	4														

<sup>a</sup>Taken at minimum (midpoint)


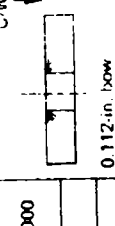
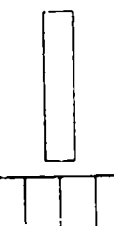
<sup>b</sup>Reamer failed (step in hole), did not fail in this hole

PHASE II - TASK 2 - BASIC OPEN HOLE VALUES  
300 M, C/W, Open, 115 KSI

TEST 259 SPECIMEN 623078 DATE 7/21/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig 2	Interference (in.)	0.0245	Nominal hole size (in.)	3/8	Max net stress (ksi)	115
Material	300 M steel (270-300 ksi)	Stress type	Push (no sleeve)	Process	Ream, C/W, ream	Max test load (kip)	32
Width (in.)	1.5	Sleeve thickness (in.)	-			Load ratio (R)	0.1
Hole spacing	1.5	Sleeve orientation	-			Test frequency	4200 cpm
Edge margin (in.)	0.75	Mandrel material	Carbide (BAC 5972)	FASTENER INSTALLATION		Test laboratory	Materials
Material grade (in.)	0.250	Mandrel taper (in/in)	0.045	Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.358	Fit	-	Test machine	100 kip Vibration
		Lubrication	Fel Pro 300 in hole and on mandrel	Torque (in. lb)	-		

Note: Spiral reamer marks in holes from withdrawal; coldworked holes more difficult to ream.

Note: Spiral reamer marks in holes from withdrawal; coldworked holes more difficult to ream.															
Specimen diag. no.	Hole no.	Hole diameter (in.)			Hole finish (HRH)			Coldwork expansion (in.)		Fastener size (in.)			Cycles to failure	Origin of failure and remarks	
		Before coldwork	After coldwork (a)	After ream	Before coldwork	After coldwork	After ream	Actual	Retained (a)	Diameter	Fit				
-20	1	0.3335	0.3500	0.3745	15	5	20	0.0245	0.0165				127,000	 C/W 0.023 in. bow	
	2	0.3335	0.3500	0.3745	-	-	-	0.0245	0.0165						
	3														
	4														
-21	1	0.3325	0.3510	0.3745	20	5	20	0.0245	0.0175				46,000	 C/W 0.112 in. bow	
	2	0.3335	0.3510	0.3745	-	-	-	0.0245	0.0175						
	3														
	4														
	1														
	2														
	3														
	4														

<sup>a</sup> Taken at minimum (midpoint)

300 M.  
open, C/W,  
3/4-in. hole  
110 ksi

TEST 11S10 SPECIMEN 62380 DATE 10/15/73

## SPECIMEN DESCRIPTION

**Fig. 2**

300 M steel (270-300 ksi)

3.00  
Weight (lb.)

Category	Value
Hole spacing	3.00

1.50

0.375

Surface treatment

## COLDWORK PROCESS

Interference (in.)

**Sleeve type**

## Sleeve 1 Pick

Sleeve orientation

**Material**

**Mandrel taper (in)**

Manfred

84

## HOLE PREPARATION

Nominal hole size (in)

## Process

STERNER INVESTIGATION

1.88

3

## FATIGUE CONDITIONS

Max nel stress (k.s.) 110

Max gross load (kN)

01

4000

7-11-1994

.....

608

Vibra

[illegible]

# PHASE II TASK 3 BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 1

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 2-6-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: HiLok (Prot HD)

### 3. CW Process

Sleeve type: -  
 Sleeve thickness: -  
 Sleeve ori-: -  
 CW Mn: -  
 CW: -  
 Major Dia.: -  
 orion: -

**NOT APPLICABLE**




### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 220-240 In/lbs

2024  
 Reamed HiLok  
 30KSI

### 4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8500 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 kip)

Specimen No. R623079	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-1	1	.3735	.3737	+.0002	45	696	
	2	.3735	.3735	NET	25		
-2	1	.3735	.3735	NET	35	565	
	2	.3735	.3735	NET	30		
-3	1	.3735	.3735	NET	30	127	
	2	.3740	.3735	-.0005	25		

# PHASE II TASK 3 BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 1a

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 2-6-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hilok (Prot HD)

### 3. CW Process

Sleeve type: \_\_\_\_\_  
 Sleeve thick: \_\_\_\_\_  
 Sleeve n: \_\_\_\_\_  
 CW: \_\_\_\_\_  
 Laper: \_\_\_\_\_  
 andrel Major Dia.: \_\_\_\_\_  
 urication: \_\_\_\_\_

**NOT APPLICABLE**



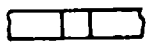
### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque - 220/240 In/lbs

2024  
 Reamed Hilok  
 30ksi

### 4. Fatigue Conditions

Net stress: 30ksi  
 Test load: 8500 lts  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophone (36Kip)

Specimen No. R623079	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-10	1	.3735	.3735	NET	45	237	 Head
	2	.3735	.3735	NET	-		
-11	1	.3740	.3740	NET	40	205	 Head
	2	.3745	.3740	-0005	-		
-	1						
	2						

# PHASE II TASK 3 BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 2

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 2-6-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hilok (Prot HD)

### 3. CW Process

Sleeve type: -  
 Sleeve thickness: -  
 Sleeve orle: -  
 CW M: -  
 Major Dia.: -  
 Location: -

**NOT APPLICABLE**



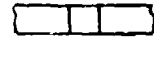
### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in/lbs

2024  
 Reamed Hilok  
 25ksi

### 4. Fatigue Conditions

Net stress: 25ksi  
 Test load: 7000 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36Kip)

Specimen No. R623079	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-4	1	.3740	.3735	-.0005	25	404	
	2	.3745	.3735	-.001	20		
-5	1	.3745	.3735	-.001	15	684	
	2	.3745	.3735	-.001	15		
-	1						
	2						

# PHASE II TASK 3 BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 3

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 2-6-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fasteners: Hilok (Prot HD)

### 3. CW Process

Sleeve type: -  
 Sleeve thickness: -  
 Sleeve or: -  
 CW: -  
 Taper: -  
 Core Major Dia.: -  
 Location: -

**NOT APPLICABLE -**



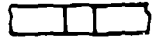
### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in/lbs

2024  
 Reamed Hilok  
 35ksi

### 4. Fatigue Conditions

Net stress: 35 ksi  
 Test load: 9950 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36Kip)

Specimen No. R623079	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-6	1	.3740	.3740	NET	20	82	
	2	.3745	.3740	NET	20		
-7	1	.3745	.3735	-.001	20	79	 burnishing under head
	2	.3740	.3735	-.0005	20		
-	1						
	2						

# PHASE II TASK 3 BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 4

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 2-6-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hilok (Prot HD)

### 3. CW Process

Sleeve type: -  
 Sleeve thickness: -  
 Sleeve ori: -  
 CW M: -  
 Upper: -  
 Incl Major Dia.: -  
 Location: -

**NOT APPLICABLE**




### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in/lbs

2024  
 Reamed Hilok  
 40 ksi

### 4. Fatigue Conditions

Net stress: 40 ksi  
 Test load: 11,400 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophone (36Kip)

Specimen No. R623079	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-8	1	.3740	.3735	-.0005	60	52	
	2	.3740	.3735	-.0005	70		
-9	1	.3745	.3736	-.0009	20	49	 burnishing fretting under head & washer
	2	.3745	.3735	-.001	20		
-	1						
	2						

# PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 5 (2024)

NOMINAL EXPANSION VALUE: 0.018" - 0.020"

## GENERAL TEST CONDITIONS

DATE: 2-8-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hilok (Prot HD)

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -O-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: 0.3738"  
 Lubrication: Fel Pro 300 (on sleeve)



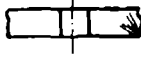
### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: C/W, Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in/lbs

2024  
 C/W Hilok  
 30ksi

### 4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,500 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophone (36Kip)

Specimen No. R623079	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-12	1	.3730	.3737	.0007	20	591	 outside
	2	.3730	.3737	.0007	20		
-13	1	.3730	.3735	.0005	25	950	 outside
	2	.3730	.3737	.0007	30		
-14	1	.3730	.3736	.0006	20	608	 fretting undernut
	2	.3730	.3737	.0007	25		

# PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3A5 (7175)

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 4-6-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 7175 T 736  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fasteners: Hilok (Prot Head)

### 3. CW Process None Used

Sleeve type: -  
 Sleeve thickness: -  
 Sleeve orien: -  
 CW M: -  
 CW: -  
 Major Dia.: -  
 Jurlon: -

NOT APPLICABLE -




### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 225-250 in/lbs

7175  
 Reamed Hilok  
 30 ksi

### 4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,550 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

Specimen No. R623079	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-1	1	.3735	.3735	0	35	359	 head
	2	.3735	.3735	0	-		
-2	1	.3735	.3735	0	35	1,007	 head
	2	.3735	.3735	0	-		
-3	1	.3735	.3735	0	40	253	
	2	.3735	.3735	0	-		

# PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 6 (2024)

NOMINAL EXPANSION VALUE: 0.018" - 0.020"

## GENERAL TEST CONDITIONS

DATE: 2-8-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hilok (Prot Head)

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12-0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: 0.3738"  
 Lubrication: Fel Pro 300 (on sleeve)



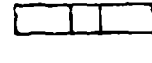
### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: C/W, Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in/lbs

2024  
 C/W Hilok  
 25 ksi

### 4. Fatigue Conditions

Net stress: 25 ksi  
 Test load: 7,000 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

Specimen No. R623079	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-15	1	.3730	.3736	.0006	25	7,779	 No Failure
	2	.3730	.3735	.0005	30		
-16	1	.3730	.3738	.0008	25	8,323	
	2	.3730	.3738	.0008	25		
	1						
	2						

# PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 6 (7175)

NOMINAL EXPANSION VALUE: .019"

## GENERAL TEST CONDITIONS

DATE: 4-6-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 7175 T 736  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hilok (Prot Head)

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.:   
 Lubrication: Fel Pro 300 (on sleeve)



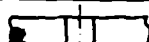
### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: C W, Ream, Install Fastener  
 Installation Torque - 225-250 in/lbs

### 4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,450 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

7175  
 CW Hilok  
 30 ksi

Specimen No. R623079	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-4	1	.3740	.3740	0	40	513	 head
	2	.3740	.3740	0	-		
-5	1	.3735	.3735	0	35	523	 head
	2	.3735	.3735	0	-		
-6	1	.3735	.3735	0	40	293	 head
	2	.3735	.3735	0	-		

# PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3 A 7

NOMINAL EXPANSION VALUE: 0.018" - 0.020"

## GENERAL TEST CONDITIONS

DATE: 2-8-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hilok (Prot. Head)

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: 0.3738"  
 Lubrication: Fel Pro 300 (on sleeve)




### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: C/W, Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in./lbs

2024  
 C/W Hilok  
 35 ksi

### 4. Fatigue Conditions

Test stress: 35 ksi  
 Test load: 9,900 lbs  
 Load ratio: (R) = 0.1  
 Test frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

Specimen No. R623079	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-17	1	.3730	.3737	.0007	25	311	
	2	.3730	.3736	.0006	30		Nut Side
-18	1	.3730	.3738	.0008	20	387	
	2	.3730	.3738	.0008	25		Head Side
	1						
	2						

# PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3 A 8

NOMINAL EXPANSION VALUE: 0.018" - 0.020"

## GENERAL TEST CONDITIONS

DATE: 2-8-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hilok (Prot Head)

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: 0.3738"  
 Lubrication: Fel Pro 300 (on sleeve)

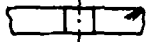


### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: C/W, Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in./lbs

### 4. Fatigue Conditions

Net stress: 40 ksi  
 Test load: 11,350 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

2024  
 C/W Hilok  
 40 ksi

Specimen No. R623079	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-19	1	.3730	.3735	.0005	25	161	 Head Side
	2	.3730	.3735	.0005	20		
-20	1	.3730	.3736	.0006	25	149	 Nut Side
	2	.3730	.3735	.0005	30		
-	1						
	2						

# PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3 A -9 a

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 2-13-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fasteners: Taperlok (Prot Head)

### 3. CW Process

Sleeve type:             
 Sleeve thickness:             
 Sleeve ID:             
 CW:             
 Taper:             
 Barrel Major Dia.:             
 Lubrication:           

**NOT APPLICABLE**




### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in./lbs

### 4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,400 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophone (36 Kip)

2024  
 Prot. Head T/L  
 30 ksi

Specimen No. R623079	Hole No.	Head Protrusion (Inches) After ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-23	1	.232	-		30	94	 Nut Side
	2	.228	-		-		
-24	1	.229	-		35	6,086	 Head Side
	2	.230	-		-		
-25	1	.231	-		20	2,662	 Head Side
	2	.230	-		-		

# PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 9b

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 3-6-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fasteners: Taperlok (Prot. Head)

### 3. CW Process

Sleeve type: -  
 Sleeve thickness: -  
 Sleeve orien: -  
 CW M: -  
 CW: -  
 Major Dia.: -  
 orien: -

**NOT APPLICABLE**




### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in-lbs

### 4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 9,450 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophone (36 Kip)

2024  
 Prot. Head T/L  
 30 ksi

Specimen No.	Hole No.	Head Protrusion (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Torque (in-lbs)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-35	1	.224			55	225	1,236	
	2	.237			-	225		
-	1							
	2							
-	1							
	2							

# PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3A-10

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 2-13-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Taperlok (Prot. Head)

### 3. CW Process

Sleeve type: -  
 Sleeve thickness: -  
 Sleeve orien: -  
 CW M: -  
 C: -  
 Major Dia.: -  
 Location: -

**NOT APPLICABLE**




### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in/lbs

2024  
 Prot. Head T/L  
 25 ksi

### 4. Fatigue Conditions

Net stress: 25 ksi  
 Test load: 7,000 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/Minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

Specimen No. R623079	Hole No.	Head Protrusion (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-26	1	.230	-	-	30	10,075	 No Failure
	2	.231	-	-	-		
-27	1	.225	-	-	30	1,594	 No Failure
	2	.231	-	-	-		
-22	1	.241	-	-	45	10,164	 No Failure
	2	.241	-	-	-		

# PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3A -11

NOMINAL EXPANSION VALUE: \_\_\_\_\_

## GENERAL TEST CONDITIONS

DATE: 2-13-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Taperlok (Prot. Head)

### 3. CW Process

Sleeve type: \_\_\_\_\_  
 Sleeve thick: \_\_\_\_\_  
 Sleeve r: \_\_\_\_\_  
 CW: \_\_\_\_\_  
 Paper: \_\_\_\_\_  
 andrel Major Dia.: \_\_\_\_\_  
 Location: \_\_\_\_\_

**- NOT APPLICABLE -**


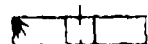
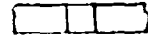
### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in./lbs

### 4. Fatigue Conditions

Net stress: 35 ksi  
 Test load: 9,800 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophone (36 Kip)

2024  
 Prot. Head T/L  
 35 ksi

Specimen No. R623079	Hole No.	Head Protrusion (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-28	1	.230			25	328	 Headside Failure
	2	.231			-		
-29	1	.232			30	369	 Headside Failure
	2	.230			-		
-	1						
	2						

# PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3A-12

NOMINAL EXPANSION VALUE:           

## GENERAL TEST CONDITIONS

DATE: 2-13-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Taperlok (Prot. Head)

### 3. CW Process

Sleeve type:             
 Sleeve thick-             
 Sleeve             
 CW             
 Taper:             
 Srel Major Dia.:             
 Location:           

**NOT APPLICABLE**

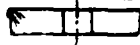


### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in./lbs

### 4. Fatigue Conditions

Net stress: 40 ksi  
 Test load: 11,250 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test laboratory: Materials  
 Test engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

2024  
 Prot. Head T/L  
 40 ksi

Specimen No. R623079	Hole No.	Head Protrusion (Inches)  After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-30	1	.234	-		25	237	
	2	.233	-		-		Headside Failure
-31	1	.232	-		30	-	
	2	.230	-		-		Spec. Overloaded No Data
-36	1	.234			50	156	
	2	.234			-		Headside Failure

# PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 13

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 2-13-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Taperlok (100° Head)

### 3. CW Process

Sleeve type: -  
 Sleeve thick: -  
 Sleeve: -  
 CW: -  
 Taper: -  
 and/or Major Dia.: -  
 Location: -

NOT APPLICABLE -



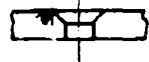
### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 225-240 in/lbs

2024  
 100° Head T/L  
 30 ksi

### 4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,475 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

Specimen No. R623079	Hole No.	Head Protrusion (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-32	1	.201	-		30	147	
	2	.190	-		-		
-33	1	.207	-		30	264	
	2	.206	-		-		
-34	1	.204	-		30	196	
	2	.202	-		-		

# PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 14

NOMINAL EXPANSION VALUE: -

## GENERAL TEST CONDITIONS

DATE: 3-9-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Taperlok (Flush Head)

### 3. CW Process

Sleeve type: -  
 Sleeve thick: -  
 Sleeve o: -  
 CW A: -  
 Taper: -  
 Jurel Major Dia.: -  
 Location: -

NOT APPLICABLE

### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener

2024  
 100° Head T/L  
 25 ksi

### 4. Fatigue Conditions

Net stress: 25 ksi  
 Test load: 7000 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

Specimen No. R623079	Hole No.	Head Protrusion (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-21	1	.204			45	612	
	2	.205			-		
-23	1	.206			40	661	
	2	.207			-		
-	1						
	2						

# PHASE II - TASK 3 - BASIC FILLED HOLE DATA

Ti-6Al-4V,  
reamed, Hi-Lok  
70 ksi

TEST 3T1 SPECIMEN 623078 DATE 9/19/73

## SPECIMEN DESCRIPTION

Fig. 2  
Configuration \_\_\_\_\_  
Material Ti-6Al-4V (annealed)  
Width (in.) 1.50  
Hole spacing 1.50  
Edge margin (in.) 0.75  
Material gauge (in.) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS

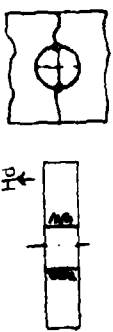
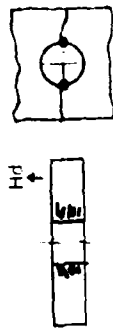
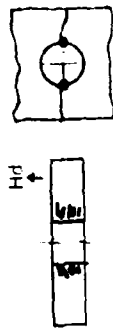
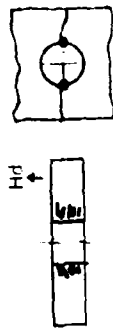
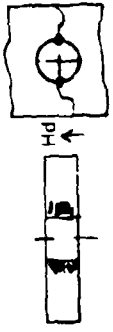
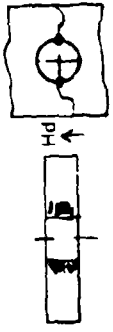
Interference \_\_\_\_\_  
Sieve type \_\_\_\_\_  
Sieve thickness (in.) \_\_\_\_\_  
Sieve orientation \_\_\_\_\_  
Mandrel material \_\_\_\_\_  
Mandrel taper (in/in) \_\_\_\_\_  
Mandrel max diameter (in.) \_\_\_\_\_  
Lubrication \_\_\_\_\_

## HOLE PREPARATION

Nominal hole size (in.) 0.375  
Process Ream  
FASTENER INSTALLATION  
Type Hi-Lok prot hd  
Fit (in.) Net to 0.0005 clearance  
Torque (in-lb) 240 to 250

## FATIGUE CONDITIONS

Max net stress (ksi) 70  
Max test load (kip) 20  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine Vibraphore 36-kip

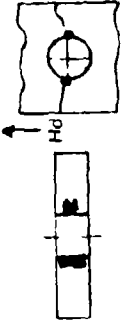

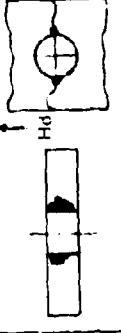

Specimen design no.	Hole no.	Hole diameter (in.)			Hole finish (HHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
1	1		0.3740				40			0.3740	Net	90,000	
	2		0.3740				--			0.3740	Net		
	3												
	4												
2	1		0.3750				50			0.3745	0.0005	83,000	
	2		0.3750				--			0.3745	0.0005		
	3												
	4												
3	1		0.3740				40			0.3740	Net	78,000	
	2		0.3740				--			0.3740	Net		
	3												
	4												

Ti-6Al-4V,  
reamed Hi-Lok,  
75 ksi

PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

TEST 312 SPECIMEN 623079 DATE 9/19/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference		Nominal hole size (in.)	0.375	Max net stress (ksi)	75
Material	Ti-6Al-4V (annealed)	Sleeve type		Process	Ream	Max test load (kip)	22
Width (in.)	1.50	Sleeve thickness (in.)				Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation				Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material		FASTENER INSTALLATION		Test laboratory	Materials
Material grade (in.)	0.250	Mandrel taper (in./in.)		Type	Hi-Lok prot hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)		Fit (in.)	Net to 0.0005 clearance	Test machine	Vibrashore 36 kip
		Lubrication		Torque (in. lb)	-340 to -360		

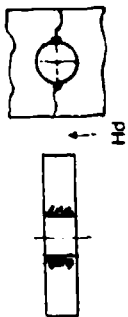
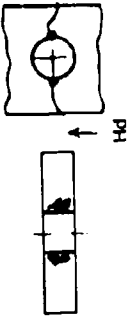
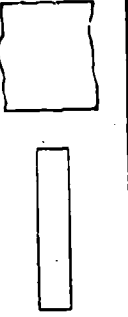
Specimen ID no.	Hole diameter (in.)	Hole finish (RH/R)				Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
4	1		0.3740		50			0.3740	Net	47,000	
	2		0.3740					0.3740	Net		
	3										
	4										
5	1		0.3740		45			0.3740	Net	52,000	
	2		0.3740					0.3740	Net		
	3										
	4										
	1										
	2										
	3										
	4										

# PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-4V  
reamed, Hi-Lok  
65 ksi

TEST 3T3 SPECIMEN 623079 DATE 9/19/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference		Nominal hole size (in.)	0.375	Max net stress (ksi)	65
Material	Ti-6Al-4V (annealed)	Sleeve type		Process	Ream	Max test load (kip)	19.3
Width (in.)	1.50	Sleeve thickness (in.)				Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation				Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material				Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)		Type	Hi-Lok prot hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)		Fit	Net to 0.0005 clearance	Test machine	36-kip Vibraphore
		Lubrication		Torque (in. lb)	240 to 250		

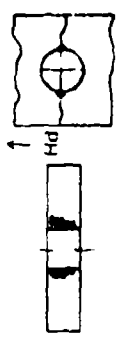
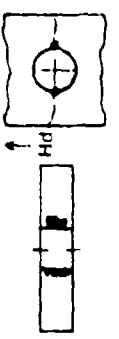



Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHRI)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
6	1			0.3740			40			0.3740	Net	199,000	
	2			0.3740			-			0.3740	Net		
	3												
	4												
7	1			0.3740			45			0.3740	Net	92,000	
	2			0.3740			-			0.3740	Net		
	3												
	4												
	1												
	2												
	3												
	4												

# PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-4V,  
reamed, Hi-Lok,  
60 ksi

TEST 314 - SPECIMEN 623079 DATE 9/19/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference		Nominal hole size (in.)	0.375	Max net stress (ksi)	60
Material	Ti-6Al-4V (annealed)	Sleeve type		Process	Ream	Max test load (kip)	17.7
Width (in.)	1.50	Sleeve thickness (in.)				Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation				Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material		FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)		Type	Hi-Lok prot hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)		Fit (in.)	Net to 0.0005 clearance	Test machine	36-Vibraphore
		Lubrication		Torque (in.-lb)	240 to 250		

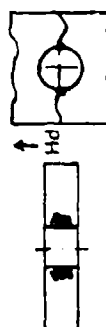
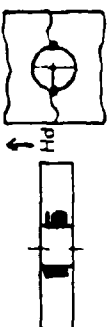
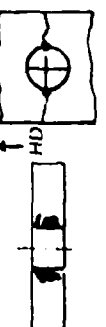
Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)			Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	After coldwork	Before coldwork	After coldwork	After ream	Actual	Reamed	Diameter	Fit			
8	1		0.3740				40			0.3740	Net		246,000	
	2		0.3740				-			0.3740	Net			
	3													
	4													
9	1		0.3740				45			0.3740	Net		139,000	
	2		0.3740				-			0.3740	Net			
	3													
	4													
	1													
	2													
	3													
	4													

# PHASE II-TASK 3-BASIC FILLED-HOLE DATA

Ti 6Al-4V sta.  
reamed, Hi-Lok,  
70 ksi

TEST 3T5 SPECIMEN 623079 DATE 9/19/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference		Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti 6Al-4V (sta)	Sleeve type		Process	Ream	Max test load (kip)	20.4
Width (in.)	1.50	Sleeve thickness (in.)				Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation				Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material				Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)		Type	Hi-Lok, prot hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)		Fit	Net to 0.0005 clearance	Test machine	36 kip Vibraphore
		Lubrication		Torque (in. lb)	240/250		

Specimen dash no	Hole no	Hole diameter (in.)				Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit			
1 sta	1		0.3740					25			0.3740	Net	65,000	
	2		0.3740					-			0.3740	Net		
	3													
	4													
2 sta	1		0.3740					20			0.3740	Net	74,000	
	2		0.3470					-			0.3740	Net		
	3													
	4													
3 sta	1		0.3740					25			0.3740	Net	82,000	
	2		0.3740					-			0.3740	Net		
	3													
	4													

# PHASE II - TASK 3 - BASIC FILLED HOLE DATA

Ti-6Al-4V stoa,  
reamed, Hi-Lok,  
70 ksi

TEST 3T6 SPECIMEN 623079 DATE 9/19/73

## SPECIMEN DESCRIPTION

Fig. 2  
Configuration \_\_\_\_\_  
Material Ti-6Al-4V (stoa)  
Width (in.) 1.50  
Hole spacing 1.50  
Edge margin (in.) 0.75  
Material gauge (in.) Shot peen  
Surface treatment \_\_\_\_\_

## COLDWORK PROCESS

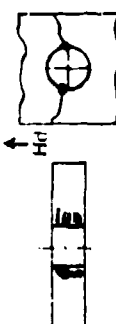
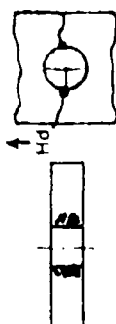
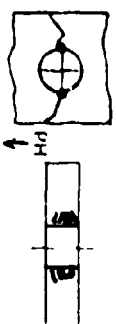
Interference \_\_\_\_\_  
Sieve type \_\_\_\_\_  
Sieve thickness (in.) \_\_\_\_\_  
Sieve orientation \_\_\_\_\_  
Mandrel material \_\_\_\_\_  
Mandrel taper (in./in.) \_\_\_\_\_  
Mandrel max diameter (in.) \_\_\_\_\_  
Lubrication \_\_\_\_\_

## HOLE PREPARATION

Nominal hole size (in.) 0.375  
Process Ream  
FASTENER INSTALLATION  
Type Hi-Lok, prot hd  
Fit Net to 0.0005 clearance  
Torque (in. lb) 240-250

## FATIGUE CONDITIONS

Max net stress (ksi) 70  
Max test load (kip) 20  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine Vibraphores




Specimen dash no.	Hole no.	Hole diameter (in.)				Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)			Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Ream (in.)	Diameter	Fit				
4 stoa	1			0.3750			35			0.3745	0.0005		82,000		
	2			0.3750			-			0.3745	0.0005				
	3														
	4														
5 stoa	1			0.3740			30			0.3740	Net		74,000		
	2			0.3740			-			0.3740	Net				
	3														
	4														
6 stoa	1			0.3740			35			0.3740	Net		69,000		
	2			0.3740			-			0.3740	Net				
	3														
	4														

# PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-6V-2Sn,  
reamed, Hi-Lok,  
70 ksi

TEST 317 SPECIMEN 623079 DATE 9/19/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference		Nominal hole size (in.)	0.375	Max. net stress (ksi)	70
Material	Ti-6Al-6V-2Sn (annealed)	Stress type		Process	Ream	Max. test load (kip)	20.2
Width (in.)	1.50	Stress thickness (in.)				Load ratio (R)	0.1
Hole spacing	1.50	Stress orientation				Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material		FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in/in)		Type	Hi-Lok, prothd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)		Fit	Net to 0.0005 clearance	Test machine	36-kip Vibrashore
		Lubrication					

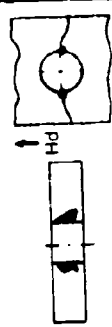
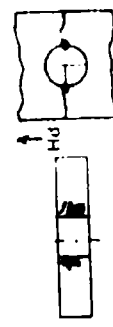
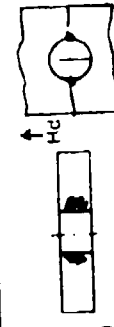
Specimen ID	Hole no.	Hole diameter (in.)				Hole finish (RA/R)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream		Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
1.662	1		0.3745							0.3740	0.0005	53,000	
	2		0.3745							0.3740	0.0005		
	3												
	4												
2.662	1		0.3745							0.3740	0.0005	43,000	
	2		0.3745							0.3740	0.0005		
	3												
	4												
3.662	1		0.3740							0.3740	Net	56,000	
	2		0.3740							0.3740	Net		
	3												
	4												

# PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-6V-2Sn sta.  
reamed, Hi-Lok,  
70 ksi

TEST 3T8 SPECIMEN 623079 DATE 9/19/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITION	
Configuration	Fig. 2	Interference		Normal hole size (in.)	0.375	Max. net stress (ksi)	70
Material	Ti-6Al-6V-2Sn (sta)	Sleeve type		Process	Ream	Max. test load (kip)	20.2
Width (in.)	1.50	Sleeve thickness (in.)				Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation				Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material		FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)		Type	Hi-Lok, prot hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)		Fit	Net to 0.0005 clearance	Test machine	36 kip Vibraphore
		Lubrication			24.250		

Specimen dash no	Hole no	Hole diameter (in.)				Hole finish (IRHR)			Coldwork expansion (in.)		Fastener size (in.)			Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit				
4-662	1			0.3740			30			0.3740	Net	54,000			
	2			0.3740			-			0.3740	Net				
	3														
	4														
5-662	1			0.3740			35			0.3740	Net	48,000			
	2			0.3740			-			0.3740	Net				
	3														
	4														
6-662	1			0.3750			30			0.3740	0.0010	29,000			
	2			0.3745			-			0.3740	0.0005				
	3														
	4														

# PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al 6V 2Sn stoa.  
reamed, Hi-Lok,  
70 ksi

TEST 3T9 SPECIMEN 623079 DATE 9/19/73

## FATIGUE CONDITIONS

Max. test stress (ksi) 70  
Min. test load (kip) 20  
Load ratio (H) 0.1  
Test frequency 4000 cpm  
Test temperature Materials  
Test technique D. Reese  
Test machine 36 kip Vibration

## HOLE PREPARATION

Nominal hole size (in.) 0.375  
Process Ream

## WORK PROCESS

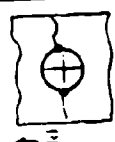

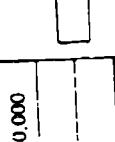
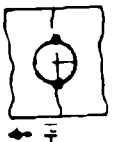
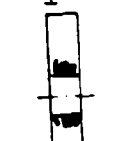
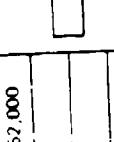

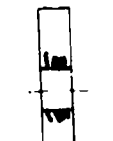
Fig. 2

Ti-6Al 6V 2Sn (sto)

Configuration Interference  
Material Sleeve type  
Width (in.) Sleeve thickness (in.)  
Hole spacing Sleeve or collation  
Edge margin (in.) Machined material  
Material grade (in.) Machined taper (in.)  
Surface treatment Machined max. diameter (in.)  
Shot peen  
Lubrication

## FASTENER INSTALLATION

Type Hi-Lok, prot hd  
Fit Net to 0.0005 clearance  
Torque (in. lb) 240-250

Specimen dash no	Hole no	Hole diameter (in.)				Hole finish (H/H)			Collwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before collwork	After collwork	After ream	After ream	Before collwork	After collwork	After ream	Actual	Retained	Diameter	Fit		
7662 sto	1		0.3740	0.3740	25						0.3740	Net	70,000	
	2		0.3740								0.3740	Net		
	3													
	4										0.3740	Net	52,000	
8662 sto	1		0.3740	0.3740	25						0.3740	Net		
	2		0.3740								0.3740	Net		
	3													
	4										0.3740	Net	51,000	
9662 sto	1		0.3740	0.3740	30						0.3740	Net		
	2		0.3740								0.3740	Net		
	3													
	4													

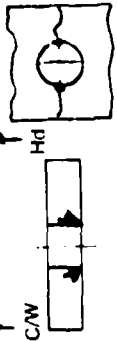
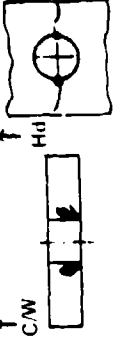
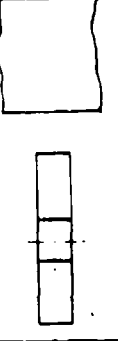


# PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-4V,  
C/W, Hi-Lok,  
65 ksi

TEST 3T11 SPECIMEN 623079 DATE 9/20/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig 2	Interference	0.019	Normal hole size (in)	0.375	Max net stress (ksi)	65
Material	Ti-6Al-4V (annealed)	Sleeve type	Split	Process	Ream, C/W, ream	Max test load (kip)	19
Width (in)	1.50	Sleeve thickness (in)	0.010			Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation	0			Test frequency	4000 cpm
Edge margin (in)	0.75	Mandrel material	AISI 9260 Steel			Test laboratory	Materials
Material gap (in)	0.250	Mandrel taper (in/in)	0.045			Test engineer	D Reese
Surface treatment	Shot peen	Mandrel max diameter (in)	0.353			Test machine	36-kip Vibration
		FASTENER INSTALLATION					
		Type		Hi-Lok, prot hd			
		Fit		Net to 0.0005 clearance			
		Torque (in lb)		240-250			
		Lubrication		Fel Pro 300			

Specimen dash no	Hole no	Hole diameter (in)			Hole finish (RHR)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
13	1	0.3545	0.3635	0.3745	30	20	30	0.0185	0.0090	0.3740	0.0005	1,333,000	
	2	0.3545	0.3635	0.3635	-	-	-	0.0184	0.0090	0.3740	0.0005		
	3												
	4												
14	1	0.3545	0.3635	0.3745	40	20	35	0.0185	0.0090	0.3740	0.0005	2,273,000	
	2	0.3545	0.3635	0.3745	-	-	-	0.0185	0.0090	0.3740	0.0005		
	3												
	4												
	1												
	2												
	3												
	4												



# PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-4V,  
C/W, Hi-Lok,  
80 ksi

TEST 3T13 SPECIMEN 623079 DATE 9/20/73

FATIGUE CONDITIONS

Max net stress (ksi) 80

Max test load (kip) 22.9

Load ratio (R) 0.1

Test frequency 4000 cpm

Test laboratory Materials

Test engineer D. Reese

Test machine 36-kip Vibraphore

SPECIMEN DESCRIPTION

Fig. 2

Configuration Ti-6Al-4V (annealed)

Material 1.50

Width (in) 1.50

Hole spacing 0.750

Edge margin (in) 0.250

Material gauge (in) Shot peen

Surface treatment

HOLE PREPARATION

Nominal hole size (in) 0.375

Process Ream, C/W, ream



FASTENER INSTALLATION

Type Hi-Lok, prot hd

Fit Met to 0.0005 clearance

Torque (in. lb) 240.250

Lubrication Fel Pro 300

Specimen dash no	Hole no	Hole diameter (in)			Hole finish (RHR)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
.17	1	0.3545	0.3635	0.3745	50	25	25	0.0185	0.0090	0.3740	0.0005	180,000	
	2	0.3545	0.3635	0.3745	-	-	-	0.0185	0.0090	0.3740	0.0005		
	3												
	4												
.18	1	0.3545	0.3635	0.3745	50	25	20	0.0185	0.0090	0.3740	0.0005	137,000	
	2	0.3545	0.3635	0.3745	-	-	-	0.0185	0.0090	0.3740	0.0005		
	3												
	4												
	1												
	2												
	3												
	4												

Ti-6Al-4V sta.  
CW, Hi-Lok,  
70 ksi

TEST 3T14 SPECIMEN 623079 DATE 9/27/73

## SPECIMEN DESCRIPTION

Fig. 2

Ti-6Al-4V (sta)

1.50

$$\text{Hole spacing} = \frac{1.56}{\dots}$$

Edge margin (in) 0.75

Material grade (in)

Surface treatment	Shot peen
-------------------	-----------

## COLLIDWORK PROCESS

## Interference

Sleeve type

Stirrer thickness (in)

## Sleeve Orientation

**Mandatory material**

Mandrel taper (in/in)

Mandel max diameter

**Abstract**

תחילת עולמנו

MOLE PREPARATION: ON

0.375

Ream, C'W, ream

Heath, C. W., Team

Hi-Lok, pro1 hd)

0005 Clearance

240.250

067047

## FATIGUE CONDITIONS

70

20

0.1

400

Ma.

6

36

Taxi machine

[illegible]

Ti-6Al-4V stoal.  
C/W, Hi-Lok.  
70 ksi

# **PHASE II - TASK 3 - BASIC FILLED-HOLE DATA**

TEST 3T15 SPECIMEN 623079 DATE 9/27/73

## **FATIGUE CONDITIONS**

Max net stress (ksi) 70  
Max test load (kip) 19.5  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 36 kis Vibraphore

## **HOLE PREPARATION**

Nominal hole size (in.) 0.375  
Process Ream, C/W, ream

## **COLDWORK PROCESS**

Interference (in.) 0.019  
Sleeve type Solid  
Sleeve thickness (in.) 0.010  
Sleeve orientation 0°  
Mandrel material AISI 9260 steel  
Mandrel taper (in./in.) 0.045  
Mandrel max diameter (in.) 0.353  
Lubrication Fel Pro 300

## **SPECIMEN DESCRIPTION**

Fig. 2  
Configuration Ti-6Al-4V stoal  
Material 1.50  
Width (in.) 1.50  
Hole spacing (in.) 0.75  
Edge margin (in.) 0.250  
Material gauge (in.) Shot peen  
Surface treatment

## **FASTENER INSTALLATION**

Type Hi-Lok, prot hd  
Fit (in.) Net to 0.0005 clearance  
Torque (in. lb) 240-250

Edge margin (in.)		0.75		Mandrel taper (in./in.)		0.353		Fit (in.)		240-250			
Material gauge (in.)		0.250		Mandrel max diameter (in.)		Fel Pro 300		Torque (in. lb)					
Surface treatment		Shot peen		Lubrication									
Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHRI)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
.10 stoal	1	0.3545	0.3635	0.3745	50	-	35	0.0185	0.0090	0.3740	0.0005	1,588,000	
	2	0.3545	0.3635	0.3745	-	-	-	0.0185	0.0090	0.3740	0.0005		
	3												
	4												
.11 stoal	1	0.3545	0.3635	0.3745	50	-	40	0.0185	0.0090	0.3740	0.0005	616,000	
	2	0.3545	0.3635	0.3745	-	-	-	0.0185	0.0090	0.3740	0.0005		
	3												
	4												
.12 stoal	1	0.3545	0.3635	0.3745	50	-	25	0.0185	0.0090	0.3740	0.0005	146,000	
	2	0.3545	0.3635	0.3745	-	-	-	0.0185	0.0090	0.3740	0.0005		
	3												
	4												

**PHASE II - TASK 3- BASIC FILLED-HOLE DATA**

Ti-6Al-6V-2Sn.  
C/W Hi-Lok,  
70 ksi

TEST 3T16 SPECIMEN 623079 DATE 9/27/73

## SPECIMEN DESCRIPTION

Configuration	Fig. 7
Material	Ti-6Al-6V-2Sn (annealed)
Width (in.)	1.50
Hole spacing (in.)	1.50
Edge margin (in.)	0.75
Material gauge (in.)	0.250
Surface treatment	Shot peen

## COLDWORK PROCESS

Interference (in.)	0.019
Sieve type	Split
Sieve thickness (in.)	0.010
Sieve orientation	0°
Mandrel material	AISI 9260 steel
Mandrel taper (in./in.)	0.045
Mandrel max diameter (in.)	0.353
Substrate	Fel Pro 300

## HOLF PREPARATION

Nominal hole size (in) 0.375


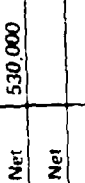
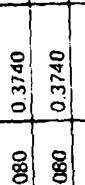
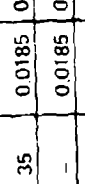

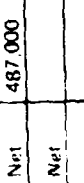
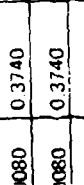
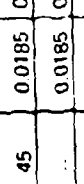

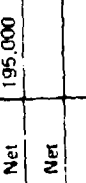
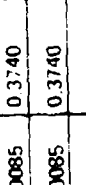
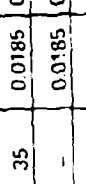
## FATIGUE CONDITIONS

Max net stress (ksi)	70
Max test load (kip)	20.6
Load ratio (R)	0.1
Test frequency	4000 cpm
Test laboratory	Materials
Test engineer	D. Reese
Test machine	36-kip Vibraphone

## FASTENER INSTALLATION

Type	Hi-Lok prot hd
Fit (in.)	Net to 0.0005 clear
	240 to 250

Torque (in ft-lb)

Specimen dash no	Hole no	Hole diameter (in.)				Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fillet			
.10	1	0.3545	0.3625	0.3740	50	25	35	0.0185	0.0080	0.3740	Net	530,000		
	2	0.3545	0.3625	0.3740	-	-	-	0.0185	0.0080	0.3740	Net			
	3													
	4													
.11	1	0.3545	0.3625	0.3740	50	25	45	0.0185	0.0080	0.3740	Net	487,000		
	2	0.3545	0.3625	0.3740	-	-	-	0.0185	0.0080	0.3740	Net			
	3													
	4													
.12	1	0.3545	0.3630	0.3740	55	25	35	0.0185	0.0085	0.3740	Net	195,000		
	2	0.3550	0.3630	0.3740	-	-	-	0.0185	0.0085	0.3740	Net			
	3													
	4													

# PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-6V-2Sn sta.  
C/W Hi Lok,  
70 ksi

TEST 3117 SPECIMEN 623079 DATE 9/27/73

## SPECIMEN DESCRIPTION

Fig. 2

Configuration	Ti-6Al-6V-2Sn (sta.)
Material	1.50
Width (in.)	1.50
Hole spacing	0.75
Edge margin (in.)	0.250
Material gage (in.)	Shot peen
Surface treatment	

## COLDWORK PROCESS

Interference (in.)	0.019
Sleeve type	Split
Sleeve thickness (in.)	0.010
Sleeve orientation	0°
Mandrel material	AISI 9260 steel
Mandrel taper (in./in.)	0.045
Mandrel max diameter (in.)	0.353
Lubrication	Fel Pro 300

## HOLE PREPARATION

Normal hole size (in.)	0.375
Process	Ream, CW, ream
FASTENER INSTALLATION	
Type	Hi Lok, prot hd
Fit	Net to 0.0005 clearance
Torque (in. ft.)	240-250

## FATIGUE CONDITIONS

Max net stress (ksi)	70
Max test load (kip)	22.8
Load ratio (R)	0.1
Test frequency	4000 gpm
Test laboratory	Materials
Test engineer	D. Reese
Test machine	36-kip Vibraphore

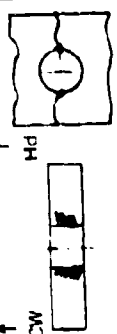
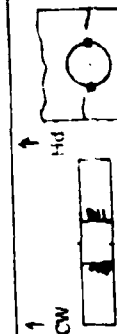
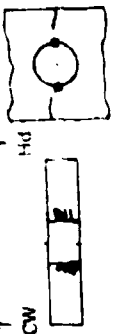
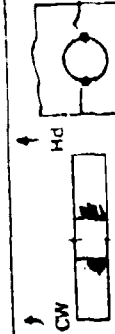
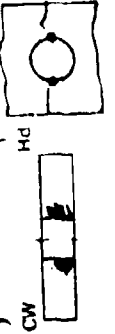

Specimen dash no.	Hole diameter (in.)				Hole finish (RHRI)				Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
	Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream			Actual	Retained	Diameter	Fit		
13	1	0.3595	0.3620	0.3740	45	25	40	0.0185	0.0075	0.3740	Net	143,000	↑ CW	↑ Hd
	2	0.3545	0.3620	0.3740				0.0185	0.0075	0.3740	Net			
	3													
	4													
14	1	0.3545	0.3620	0.3740	50	25	35	0.0185	0.0075	0.3740	Net	98,000	↑ CW	↑ Hd
	2	0.3545	0.3625	0.3740				0.0185	0.0080	0.3740	Net			
	3													
	4													
15	1	0.3545	0.3625	0.3740	50	25	40	0.0185	0.0080	0.3740	Net	110,000	↑ CW	↑ Hd
	2	0.3545	0.3625	0.3740				0.0185	0.0080	0.3740	Net			
	3													
	4													

Ti-6Al-5V 2Sn stoal.  
C/W, Hi-Lok,  
70 ksi

# PHASE II - TASK 3 - BASIC FILLED HOLE DATA

TEST 3T18 SPECIMEN 623079 DATE 9/20/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference (in.)	0.019	Normal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti-6Al-2Sn (stoal)	Sleeve type	Split	Process	Ream, C/W, ream	Max test load (kip)	20
Width (in)	1.50	Sleeve thickness (in)	0.010			Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation	0°			Test frequency	4000 cpm
Edge margin (in)	0.75	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in)	0.250	Mandrel taper (in/in)	0.045	Type	Hi-Lok, prot hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in)	0.353	Fit (in.)	Net to 0.005 clearance	Test machine	36-kip Vibraphore
		Lubrication	Fel Pro 300	Torque (in lb)	240 250		

Specimen dash no	Hole no	Hole diameter (in.)				Hole finish (RHR)			Coldwork imperfections (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Reamed	Diameter	F-T			
16 662 Stoal	1	0.3545	0.3630	0.3735	45	20	45	0.0185	0.0085	0.3735	Net	197,000		
	2	0.3545	0.3630	0.3735	-	-	-	0.0185	0.0085	0.3735	Net			
	3													
	4													
17 662 Stoal	1	0.3545	0.3630	0.3735	45	20	50	0.0185	0.0085	0.3735	Net	90,000		
	2	0.3545	0.3630	0.3735	-	-	-	0.0185	0.0085	0.3735	Net			
	3													
	4													
18 662 Stoal	1	0.3545	0.3630	0.3735	50	25	45	0.0185	0.0085	0.3735	Net	147,000		
	2	0.3545	0.3630	0.3735	-	-	-	0.0185	0.0085	0.3735	Net			
	3													
	4													

# PHASE II - TASK 3 - BASIC FILLED HOLE DATA

Ti 6Al 4V  
prot hd, Taper Lok,  
70 ksi

TEST 3119 SPECIMEN 623079 DATE 10/19/73

SPECIMEN DESCRIPTION		COLL WORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference		Normal hole size (in.)	0.375	Min net stress (ksi)	70
Material	Ti 6Al 4V (annealed)	Sleeve type		Process	Ream	Max test load (kip)	20
Width (in.)	1.50	Sleeve thickness (in.)				Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation				Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material		FASTENER INSTALLATION			
Material grade (in.)	0.250	Mandrel taper (in/in)		Type	Taper Lok, prot hd	Test laboratory	Materials
Surface treatment	Shot peen	Mandrel max diameter (in.)		Fir (in)	Blowing class F (0.187 0.289)	Test engineer	D. Reese
		Lubrication		Torque (in ft)	240 250	Test machine	36 kip Vibratron

Specimen dash no.	Hole no.	Hole diameter (in.)				Hole finish (IR4R)			Collwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before collwork	After collwork	After ream.	Before collwork	After collwork	After ream.	Actual	Retained	Diameter	Fir			
19	1			0.240			20				Class F	367,000		
	2			0.240							Class F			
	3													
	4													
20	1			0.240			25				Class F	689,000		
	2			0.240			-				Class F			
	3													
	4													
21	1			0.230			15				Class F	5,323,000		
	2			0.230			-				Class F			
	3													
	4													

T1-6A14V  
prot hd, Taper Lok,  
75 ksi

### EXPERIMENTAL CONDITIONS

## Fig.

150

1.50

0.75

0.250

St or been  
surface treatment

11/19/2019

514000 10000

Shoreline Industries

**Steve Drent**

## Market

**Abstract**

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## 0375

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## Taper Lok. prot hd

10

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10

## 76

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0.17

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# PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-4V,  
prot hd, Taper Lok,  
65 ksi

TEST 3T21 SPECIMEN 623079 DATE 10/18/73

## SPECIMEN DESCRIPTION

Fig. 2  
Ti-6Al-4V (annealed)  
1.50  
1.50  
0.75  
0.250  
Shot peen

## COLDWORK PROCESS

Interference  
Sleeve type  
Sleeve thickness (in)  
Sleeve orientation  
Mandrel material  
Mandrel taper (in/in)  
Mandrel max diameter (in)  
Lubrication

## HOLE PREPARATION

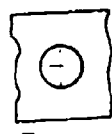
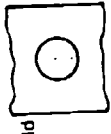

Nominal hole size (in) 0.375  
Process Ream

## FASTENER INSTALLATION

Type Taper Lok prot hd  
Fit (in.) Boeing class F (0.187-0.283)  
Torque (in lb) 240-250

## FATIGUE CONDITIONS

Max net stress (ksi) 65  
Max test load (kip) 19  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 36-kip Vibraphore

Specimen dish no	Hole no	Hole diameter (in)				Hole finish (RH/R)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
-24	1			0.230				15				Class F	7,788,000	 Hd No failure
	2			0.240				-				Class F		
	3													
	4													
-25	1			0.230				10				Class F	7,774,000	 Hd No failure
	2			0.235				-				Class F		
	3													
	4													
	1													 No failure
	2													
	3													
	4													

Ti-6Al-4V.  
prot hd, Taper Lok  
60 ksi

TEST 3T22 SPECIMEN 623079 DATE 10/18/73

## FATIGUE CONDITIONS

Configuration	Fig. 2
Material	Ti-6Al-4V (annealed)
Width (in.)	1.50
Hole spacing	1.50
Edge margin (in.)	0.75
Material gauge (in.)	0.250
Surface treatment	Shot peen

## COLDWORK PROCESS

Interference	_____
Sleeve type	_____
Sleeve thickness (in.)	_____
Sleeve orientation	_____
Mandrel material	_____
Mandrel taper (in./in.)	_____
Mandrel max diameter (in.)	_____
Lubrication	_____

## HOLE PREPARATION

Nominal hole size (in.)	Ream
0.375	

## FATIGUE CONDITIONS

Max net stress (ksi)	60
Max test load (kip)	17.5
Load ratio (R)	0.1
Test frequency	4000 cpm
Test laboratory	Materials
Test engineer	D. Reese
Test machine	36-kip Vibrapher

## FASTENER INSTALLATION

Type	Taper Lok profile
F1 (in.)	Boeing class F (0.187-0.289)
Taper (in./in.)	240-250

## Lysine







[illegible]

# PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-4V,  
flush hd, Taper Lock  
70 ksi

TEST 3123 SPECIMEN 623079 DATE 10/18/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference		Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti-6Al-4V (annealed)	Sleeve type		Process	Ream	Max test load (kip)	20
Width (in.)	1.50	Sleeve thickness (in.)				Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation				Test frequency	4000 cpm
Edge margin (in.)	0.075	Mandrel material		FASTENER INSTALLATION			
Material gauge (in.)	0.250	Mandrel taper (in/in)		Type	Taper Lok, flush hd	Test laboratory	Materials
Surface treatment	Shot peen	Mandrel max diameter (in.)		Fit (in.)	Boeing class F (0.187-0.289)	Test engineer	D. Reese
		Lubrication		Torque (in. lb)	240-250	Test machine	36 kip Vibraphore

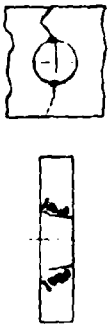
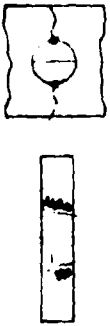
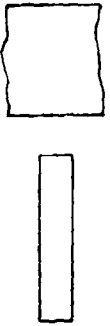
Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (HRH)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks	
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit			
28	1		0.206					20			Class F	1,146,000	 	
	2		0.201				-				Class F			
	3													
	4													
29	1		0.201					20			Class F	240,000	 	
	2		0.202				-				Class F			
	3													
	4													
30	1		0.200					25			Class F	370,000	 	
	2		0.217				-				Class F			
	3													
	4													

# PHASE II-TASK 3- BASIC FILLED-HOLE DATA

Ti-6Al-4V,  
flush hd, Taper Lok,  
75 ksi

TEST 3124 SPECIMEN 623079 DATE 10.19.73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference		Nominal hole size (in.)	0.375	Max net stress (ksi)	75
Material	Ti-6Al-4V (annealed)	Sleeve type		Process	Ream	Max test load (kip)	21.5
Width (in.)	1.50	Sleeve thickness (in.)				Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation				Test frequency	4000 gpm
Edge margin (in.)	0.75	Mandrel material		FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in/in)		Type	Paper Lok (flush hd)	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)		Fit	Boeing Class F (0.187-0.289)	Test machine	36 kip Vibraphore
		Lubrication		Torque (in. lb)	240-250		

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (IRHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
31	1		0.202				20				Class F	372,000	
	2		0.208				-				Class F		
	3												
	4												
32	1		0.1920				20				Class F	99,000	
	2		0.1930				-				Class F		
	3												
	4												
	1												
	2												
	3												
	4												

# PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-4V,  
flush hd, Taper Lok,  
65 ksi

TEST 3T25 SPECIMEN 623079 DATE 10/19/73

## SPECIMEN DESCRIPTION

Fig. 2  
Configuration \_\_\_\_\_  
Material Ti-6Al-4V (annealed)  
Width (in) 1.50  
Hole spacing 1.50  
Edge margin (in) 0.75  
Material gauge (in) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS



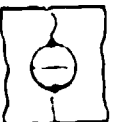

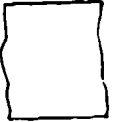
Interference \_\_\_\_\_  
Sleeve type \_\_\_\_\_  
Sleeve thickness (in) \_\_\_\_\_  
Sleeve orientation \_\_\_\_\_  
Mandrel material \_\_\_\_\_  
Mandrel taper (in/in) \_\_\_\_\_  
Mandrel max diameter (in) \_\_\_\_\_  
Lubrication \_\_\_\_\_

## HOLE PREPARATION

Nominal hole size (in) 0.375  
Process Ream  
FASTENER INSTALLATION  
Type Taper Lok, flush hd  
Fit Boeing Class F (0.187-0.289)  
Torque (in lb) 240-250

## FATIGUE CONDITIONS

Max net stress (ksi) 65  
Max test load (kip) 19  
Load ratio (R) 0.1  
Test frequency 4000/cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 36 kip Vibrashore

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHRI)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retainer	Diameter	F-it		
33	1		0.214				20				Class F	266,000	
	2		0.206				-				Class F		
	3												
	4												
34	1		0.197				25				Class F	563,000	
	2		0.198				-				Class F		
	3												
	4												
	1												
	2												
	3												
	4												

Ti-6Al-4V,  
flush hd, Taper Lok,  
60 ksi

TEST 3T26 SPECIMEN 623079 DATE 10/19/73

## COLDWORK PROCESS

**1000000**

SECRET

Sleeve thickness (in)

**Sleeve orientation:**

**Journal Inquiry**

Mandrel taper (in/in)

Mandrel max diameter (in.)

**Lucy C. Storch**

0.375

Ream

Taper/Lok, flush hd

loss F (0.187-0.289)

240-250

50

17.5

0.1

4000 cpm

## Materials

D. Reese

36 kip Vibraphore

304

PHASE II - TASK 3 - BASIC FILLED-HOLE VALUES  
300 M, Ream, Filled, 100 KSI

TEST 3S1 SPECIMEN 623079 DATE 8/14/73

SPECIMEN DESCRIPTION

Fig. 2  
 Configuration 300 M steel (270-300 ksi)  
 Material 300 M steel (270-300 ksi)  
 Width (in.) 1.50  
 Hole spacing 1.50  
 Hole margin (in.) 0.75  
 Material gauge (in.) 0.250  
 Surface treatment Shot peen

COLDWORK PROCESS

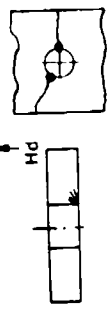
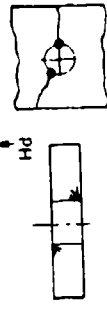

Interference -  
 Sleeve type -  
 Sleeve thickness (in.) -  
 Sleeve orientation -  
 Mandrel material -  
 Mandrel taper (in./in.) -  
 Mandrel max diameter (in.) -  
 Lubrication -

HOLE PREPARATION

Nominal hole size (in.) 3/8  
 Process Ream, install fastener  
 FASTENER INSTALLATION  
 Type Hi-Lok, prot hd (steel)  
 Fit (in.) 0.0005-0.0010 clearance  
 Torque (in. lb) 240

FATIGUE CONDITIONS

Max net stress (ksi) 100  
 Max test load (kip) 28.1  
 Load ratio (R) 0.1  
 Test frequency 4200 com  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100 kip Vibrashore

Specimen dash no	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
	Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
-1	1		0.3745			10			0.3735	+0.001	112,000	
	2		0.3745			-			0.3735	+0.001		
	3											
	4											
-2	1		0.3745			10			0.3740	+0.0005	237,000	
	2		0.3745			-			0.3740	+0.0005		
	3											
	4											
	1											
	2											
	3											
	4											

300 M. Ream. Filled, 105 KSI

TEST 352 SPECIMEN 623079 DATE 8/14/73

## Fig. 2

Configuration

Stave thickness in ft

### Slave operation

•

ה'תשנ"א

COL DWARK PROCESS

Intercept: 0

2000

Manuel Inalaya

Manfred Weber

Mandrel max. diameter (in).

## FASTENER INSTALLATION

Hi-Lok, pro<sup>1</sup> hd (steel)

0.0005 0.0015 clearance

340

## FATIGUE CONDITIONS

105

292

3

# Introduction

Approved: \_\_\_\_\_  
Special Agent in Charge

100-kip Vibrator

[illegible]

# PHASE II - TASK 3 - BASIC FILLED HOLE VALUES

300 M, Ream, Filled, 110 KSI

TEST: 353 SPECIMEN: 623079 DATE: 8/14/73

## SPECIMEN DESCRIPTION

Configuration	Fig. 2
Material	300 M steel (270-300 ksi)
Width (in.)	1.50
Hole spacing	1.50
Edge margin (in.)	0.75
Material grade (in.)	0.250
Surface treatment	Shot peen

## COLDWORK PROCESS

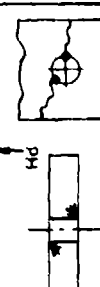
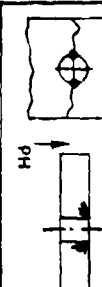
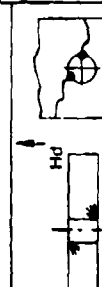
Interference	—
Sleeve type	—
Sleeve thickness (in.)	—
Sleeve orientation	—
Mandrel material	—
Mandrel taper (in./in.)	—
Mandrel max diameter (in.)	—
Lubrication	—

## HOLE PREPARATION

Nominal hole size (in.)	3/8
Process	Ream, install fastener
FASTENER INSTALLATION	
Type	Hi-Lok, prot hd (steel)
Fit (in.)	0.0005 0.0010 clearance
Torque (in. lb)	240

## FATIGUE CONDITIONS

Max out stress (ksi)	110
Max test load (kip)	31
Load ratio (R)	0.1
Test frequency	4200 cpm
Test laboratory	Materials
Test engineer	D. Reese
Test machine	100 kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHS)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	E:		
-5	1		0.3745						0.3740	+0.0005	76,000	 Large fatigue growth zones
	2		0.3745						0.3740	+0.0005		
	3											
	4											
-6	1		0.3745						0.3735	+0.0010	90,000	 Large fatigue growth zones
	2		0.3745						0.3735	+0.0010		
	3											
	4											
-7	1		0.3745						0.3740	+0.0005	62,000	 Large fatigue growth zones
	2		0.3745						0.3740	+0.0005		
	3											
	4											

## 300 M, Ream, Filled, 115 KSI

TEST 3S4 SPECIMEN 623079 DATE 8/14/73

## Fig. 2

2

300 M steel (270-300 ksi)

1.50

Hole spacing

---

1.50

Edge margin (in ) 0.75

Material code (in.)	0.250
---------------------	-------

Surface treatment	Shot peen
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10
11	11
12	12
13	13
14	14
15	15
16	16
17	17
18	18
19	19
20	20
21	21
22	22
23	23
24	24
25	25
26	26
27	27
28	28
29	29
30	30
31	31
32	32
33	33
34	34
35	35
36	36
37	37
38	38
39	39
40	40
41	41
42	42
43	43
44	44
45	45
46	46
47	47
48	48
49	49
50	50
51	51
52	52
53	53
54	54
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56	56
57	57
58	58
59	59
60	60
61	61
62	62
63	63
64	64
65	65
66	66
67	67
68	68
69	69
70	70
71	71
72	72
73	73
74	74
75	75
76	76
77	77
78	78
79	79
80	80
81	81
82	82
83	83
84	84
85	85
86	86
87	87
88	88
89	89
90	90
91	91
92	92
93	93
94	94
95	95
96	96
97	97
98	98
99	99
100	100

## Interference

Stevens

Sieve thickness (in.)

Sieve orientation

**Manuscript material**

Market order (market)

Mandrel max diameter

Lubrication

Normal hole size (in)

## Process

**† ASTENER INSTALLATION**

Typ.	Hi-L
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10
11	11
12	12
13	13
14	14
15	15
16	16
17	17
18	18
19	19
20	20
21	21
22	22
23	23
24	24
25	25
26	26
27	27
28	28
29	29
30	30
31	31
32	32
33	33
34	34
35	35
36	36
37	37
38	38
39	39
40	40
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50	50
51	51
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54	54
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56	56
57	57
58	58
59	59
60	60
61	61
62	62
63	63
64	64
65	65
66	66
67	67
68	68
69	69
70	70
71	71
72	72
73	73
74	74
75	75
76	76
77	77
78	78
79	79
80	80
81	81
82	82
83	83
84	84
85	85
86	86
87	87
88	88
89	89
90	90
91	91
92	92
93	93
94	94
95	95
96	96
97	97
98	98
99	99
100	100

Fit (in.) 0.00

Torque (in lb.)

11598 5501885 2012 1000000

Max test load (N)

Lowrance (R)

## Test frequency

4. 10. 1941 15.3.1

**Test engineer**

Test machine

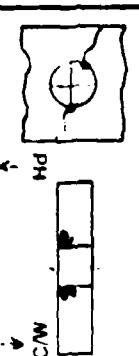
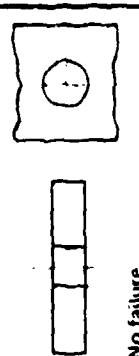
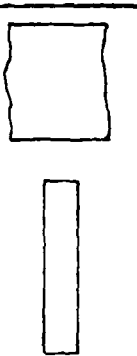
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# PHASE II - TASK 3 - BASIC FILLED-HOLE VALUES

300 M  
C/W, net fit Hi Lok,  
100 ksi

TEST 355 SPECIMEN 623079 DATE 8/27/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration		Interference (in.)	0.023	Nominal hole size (in.)	0.375	Max net stress (ksi)	100
Material	300 M steel (270-300 ksi)	Sleeve type	Push, no sleeve	Process	Ream, C/W, ream	Max test load (kip)	28
Width (in.)	1.50	Sleeve thickness (in.)				Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation				Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material	Carbide (BAC 5972)	FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)	0.045	Type	Hi-Lok prot hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.358	Fit (in.)	Net to 0.0005 clearance	Test machine	100-kip Vibrashore
Lubrication		Fel Pro 300		Torque (in. lb)		240-250	

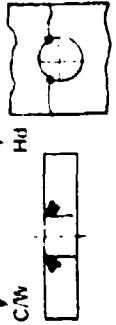
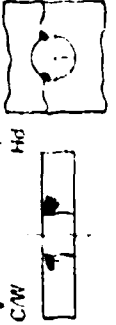
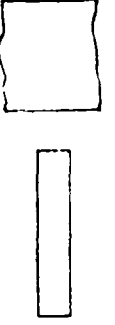
Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
10	1	-	-	0.3740	-	-	20	-	-	0.3735	0.0005	673,000	
	2	-	-	0.3740	-	-	-	-	-	0.3735	0.0005		
	3	-	-										
	4	-	-										
11	1	-	-	0.3735	-	-	20	-	-	0.3730	0.0005	8,300,000	
	2	-	-	0.3735	-	-	-	-	-	0.3730	0.0005		
	3	-	-										
	4	-	-										
	1											No failure	
	2												
	3												
	4												

# PHASE II - TASK 3 - BASIC FILLED-HOLE VALUES

300 M  
C/W, net fit, Hi Lok,  
105 ksi

TEST 3S6 SPECIMEN 623079 DATE 8/27/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration		Interference (in.)	0.0235	Nominal hole size (in.)	0.375	Max net stress (ksi)	105
Material	300 M steel (270-300 ksi)	Sleeve type	Push, no sleeve	Process	Ream, C/W, ream	Max test load (kip)	29
Width (in.)	1.50	Sleeve thickness (in.)				Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation				Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material	Carbide (BAC 5972)	FASTENER INSTALLATION		Test laboratory	Materials
Material gage (in.)	0.250	Mandrel taper (in/in)	0.045	Type	Hi Lok prot hd	Test engineer	O. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.358	Fit (in.)	Net to 0.0005 clearance	Test machine	100 kip Vibraphore
		Lubrication	Fel Pro 300	Torque (in.-lb)	240-250		

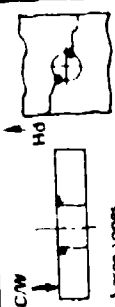
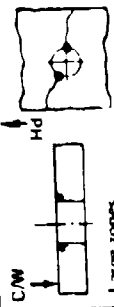
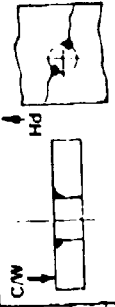
Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
.12	1	-	-	0.3735	-	-	30	-	-	0.3735	Net	462,000	
	2	-	-	0.3735	-	-	-	-	-	0.3735	Net		
	3	-	-	-	-	-	-	-	-	-	-		
	4	-	-	-	-	-	-	-	-	-	-		
.13	1	-	-	0.3735	-	-	25	-	-	0.3735	Net	4,203,000	
	2	-	-	0.3735	-	-	-	-	-	0.3735	Net		
	3	-	-	-	-	-	-	-	-	-	-		
	4	-	-	-	-	-	-	-	-	-	-		
1	1	-	-	-	-	-	-	-	-	-	-		
2	2	-	-	-	-	-	-	-	-	-	-		
3	3	-	-	-	-	-	-	-	-	-	-		
4	4	-	-	-	-	-	-	-	-	-	-		

PHASE II - TASK 3 - BASIC FILLED-HOLE VALUES  
300 M, C/W, Filled, 110 KSI, 0.045 Taper, 0.023-0.0245 Interference

TEST 357 SPECIMEN 623079 DATE 8/17/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig 2	Interference (in)	<u>0.0230/0.0245</u>	Nominal hole size (in)	<u>3/8</u>	Max net stress (ksi)	<u>110</u>
Material	<u>300 M steel (270-300 ksi)</u>	Stress type	<u>Push (no sleeve)</u>	Process	<u>C/W, ream, install fastener</u>	Max test load (kips)	<u>31</u>
Width (in)	<u>1.50</u>	Slit (in)	<u>-</u>			Load ratio (R)	<u>0.1</u>
Hole spacing	<u>1.50</u>	Slit orientation	<u>-</u>			Test frequency	<u>4700 cpm</u>
Edge margin (in)	<u>0.75</u>	Master material	<u>Carbide (BAC 5972)</u>	FASTENER INSTALLATION		Test laboratory	<u>Materials</u>
Material gap (in)	<u>0.250</u>	Master taper (in/in)	<u>0.045</u>	Type	<u>Hi-Lok, prot hd (steel)</u>	Test engineer	<u>D Reese</u>
Surface treatment	<u>Shot peen</u>	Master max diameter (in)	<u>0.358</u>	Fit (in)	<u>Net to 0.0005 clearance</u>	Test machine	<u>100 kip Vibration</u>
		Lubrication	<u>Fel Pro in hole and on mandrel</u>	Torque (in-lb)	<u>240</u>		

on mandrel.

Specimen dash no	Hole no	Hole diameter (in)			Hole finish (RH)			Conform expansion (in)		Fastener size (in)		Cycle to failure	Origin of failure and remarks
		Before collinear	After collinear	After ream	Before rollwork	After rollwork	After ream	Actual	Retained	Diameter	Fit		
-14	1			0.3740			10	0.0245		0.3735	0.0005	141,000	
	2			0.3740			-	0.0245		0.3735	0.0005		
	3												
	4												
-15	1			0.3745			15	0.0230		0.3740	0.0005	382,000	
	2			0.3745			-	0.0230		0.3740	0.0005		
	3												
	4												
-16	1			0.3740			15	0.0230		0.3740	Net	252,000	
	2			0.3745			-	0.0230		0.3740	0.0005		
	3												
	4												

300 M  
C/W, net fit, Hi-Lok  
115 ksi

TEST 358 SPECIMEN 623079 DATE 8/27/73

## SPECIMEN DESCRIPTION:

Configuration	300 M steel (270-300 ksi)
Material	
Width (in.)	1.50
Hole spacing (in.)	1.50
Edge margin (in.)	0.75
Material gage (in.)	0.250
Surface treatment	Shot peen

## COLDWORK PROCESS

Interference (in.)

Sleeve type

Sleeve thickness (in.)

Sleeve orientation

Mandrel material

Mandrel taper (in./in.)

Mandrel max. diameter

Lubrication

## HOI F PREPARATION

[illegible]

## Carbide (BAC 2972) CASIENR INSTALLATION

0.045	Type	Hi-LOK, printed
0.358	Fit (in.)	Net to 0.0050 clean
End Per. 300	Torque (in. lb)	240-250

## EXHAUSTIVE CONDITIONS




Max net stress (ksi)	115
Max test load (kip)	32
Load ratio (R)	0.1
Test frequency	4000 cpm
Test laboratory	Materials
Test engineer	D. Reese
Test notes	100-kip Vibraphore

[illegible]

PHASE II - TASK 3 - BASIC FILLED-HOLE VALUES  
300 M, C/W, Filled, 110 KSI, 0.030 Taper, 0.0245 Interference

TEST: 3S9 SPECIMEN: 623079 DATE: 8/16/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference	0.0245	Nominal hole size (in.)	3/8	Max. net stress (ksi)	110
Material	300 M steel (270-300 ksi)	Sleeve type	Push (no sleeve)	Process	C/W, ream, install fastener	Max. test load (kip)	31.4
Width (in.)	1.50	Sleeve thickness (in.)	-			Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation	-			Test frequency	4200 cpm
Edge margin (in.)	0.75	Mandrel material	Carbide (BAC 5972)	FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)	0.030	Type	Hi-Lok, prot hd (steel)	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.758	Fit (in.)	0.0005, 0.0010 clearance	Test machine	100 kip Vibrashore
		Lubrication	Fel Pro .000 in hole and on mandrel	Torque (in. lb)	240		

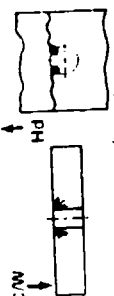
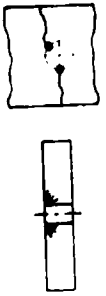
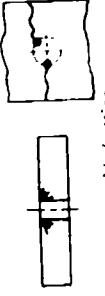
Specimen dash no.	Specimen no.	Hole diameter (in.)				Hole finish (RHRI)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
-19	1			0.3740				10	0.0245		0.3730	0.0010	390,000	 C/W 45° shank fretting— rusty fretting products Hd C/W
	2			0.3740				—	0.0245		0.3735	0.0005		
	3													
	4													
-20	1			0.3740				10	0.0245		0.3730	0.0010	349,000	 C/W 45° shank fretting— rusty fretting products Hd C/W
	2			0.3740				—	0.0245		0.3735	0.0005		
	3													
	4													
-21	1			0.3740				10	0.0245		0.3735	0.0005	264,000	 C/W 45° shank fretting— rusty fretting products Hd C/W
	2			0.3740				—	0.0245		0.3735	0.0005		
	3													
	4													

# PHASE II - TASK 3 - BASIC FILLED-HOLE VALUES

300 M, C/W, Filled, 110 KSI, 0.045 Taper, 0.020 Interference

TEST 3S10 SPECIMEN 623079 DATE 8/16/73

SPECIMEN DESCRIPTION		COLLWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig 2	Interference (in.)	0.0195	Nominal hole size (in.)	3/8	Max net stress (ksi)	110
Material	300 M steel (270-300 ksi)	Sleeve type	Push (no sleeve)	Process	C/W, ream, install fastener	Max test load (kip)	31
Width (in.)	1.50	Sleeve thickness (in.)				Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation				Test frequency	4200 cpm
Edge margin (in.)	0.75	Mandrel material	Carbide (BAG-5972)	FASTENER INSTALLATION		Test lubricant	Materials
Material size (in.)	0.250	Mandrel taper (in/in)	0.045	Type	Hi Lok, prol hd (steel)	Test equipment	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.3580	Fit	Net	Test machine	100-kip Vibration
		Lubrication	Fel Pro 300 on sleeve	Torque (in lb)	240		

Specimen dash no	Hole no	Hole diameter (in)			Hole finish (RH)			Collwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before collwork	After collwork	After ream	Before collwork	After collwork	After ream	Actual	Retained	Diameter	Fit		
-22	1		0.3740				15	0.0195		0.3740	Net	121,000	
	2		0.3740				-	0.0195		0.3740	Net		
	3												
	4												
-23	1		0.3740				15	0.0195		0.3740	Net	118,000	
	2		0.3740				-	0.0195		0.3740	Net		
	3												
	4												
-24	1		0.3740				15	0.0195		0.3740	Net	105,000	
	2		0.3740				-	0.0195		0.3740	Net		
	3												
	4												

# PHASE II - TASK 3 - BASIC FILLED-HOLE VALUES

300 M  
C/W, net fit, Hi-Lok,  
(0.015 taper mandrel),  
110 ksi

TEST 3S11 SPECIMEN 623079 DATE 8/27/73

## SPECIMEN DESCRIPTION

Fig. 2  
Configuration 300 M steel (270-300 ksi)  
Material 1.50  
Width (in.) 1.50  
Hole spacing (in.) 0.75  
Edge margin (in.) 0.250  
Material grade (in.) Shot peen  
Surface treatment

## COLDWORK PROCESS

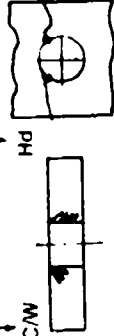
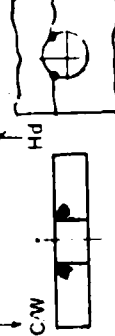
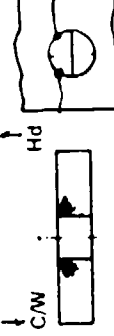
Interference (in.) 0.023  
Sleeve type Push, no sleeve  
Sleeve thickness (in.)  
Sleeve orientation  
Mandrel material Carbide-BAC 5972  
Mandrel taper (in./in.) 0.015  
Mandrel max diameter (in.) 0.358  
Lubrication Fel Pro 300

## HOLE PREPARATION

Nominal hole size (in.) 0.375  
Process Ream, C/W, ream  
FASTENER INSTALLATION  
Type Hi-Lok, prct hd  
Fit (in.) Net to 0.0005 clearance  
Torque (in. lb) 240-250

## FATIGUE CONDITIONS

Max net stress (ksi) 110  
Max test load (kip) 31  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 100-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHRI)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
-25	1	-	0.3735	0.3735	-	-	25	-	-	0.3730	0.0005	287,000	
	2	-	0.3735	0.3735	-	-	-	-	-	0.3730	0.0005		
	3	-	-	-	-	-	-	-	-	-	-		
	4	-	-	-	-	-	-	-	-	-	-		
-26	1	-	0.3735	0.3735	-	-	25	-	-	0.3735	Net	364,000	
	2	-	0.3735	0.3735	-	-	-	-	-	0.3735	Net		
	3	-	-	-	-	-	-	-	-	-	-		
	4	-	-	-	-	-	-	-	-	-	-		
-27	1	-	0.3740	0.3740	-	-	20	-	-	0.3740	Net	76,000	
	2	-	0.3740	0.3740	-	-	-	-	-	0.3740	Net		
	3	-	-	-	-	-	-	-	-	-	-		
	4	-	-	-	-	-	-	-	-	-	-		

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 A 1

NOMINAL EXPANSION VALUE: .019"

## GENERAL TEST CONDITIONS

DATE: 3-27-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig 2  
Width: 1.50"  
Hole spacing: 1.50"  
Edge margin: 0.75"  
Material: 2024 T 851  
Material gauge: 0.250"  
Surface Treatment: Shot Peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.010"  
Sleeve orientation: 90°  
CW Mandrel: SI 5300-CBM-12  
CW Mandrel Taper: 0.045"/"  
CW Mandrel Major Dia.: .3730"  
Lubrication: Fel Pro 300 (on sleeve)





### 2. Hole Preparation

Nominal hole size: 3/8"  
Process: ream, CW & ream

### 4. Fatigue Conditions

Net stress: 30 ksi  
Test load: 8,500 lbs.  
Load ratio: (R) 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophore (36 KIP)

90° Sleeve  
Open Hole

Specimen No. R62308(i)	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-21	1	.3540	.3665	.3735	60	30	40	.0190	.0125	382	 C/W
	2	.3545	.3665	.3735	60	30	-	.0185	.0120		
-22	1	.3545	.3665	.3735	50	20	45	.0185	.0120	424	 C/W
	2	.3545	.3670	.3735	55		-	.0185	.0125		
-23	1	.3540	.3665	.3735	60	30	35	.0190	.0125	335	 C/W
	2	.3540	.3665	.3735	55	20	-	.0190	.0125		

 Taken at Minimum (midpoint)

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 A 2

NOMINAL EXPANSION VALUE: .0195"

## GENERAL TEST CONDITIONS

DATE: 4-17-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig 2  
Width: 1.50"  
Hole spacing: 1.50"  
Edge margin: 0.75"  
Material: 2024 T 851  
Material gauge: 0.250"  
Surface Treatment: Shot Peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.010"  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM-12 -0-N  
CW Mandrel Taper: .045"/"  
CW Mandrel Major Dia.: .353"  
Lubrication: Fel Pro 300 (on sleeve)





### 2. Hole Preparation

Nominal hole size: 3/8"  
Process: \* Drill CW & ream  
\* Drill with Precision Drill

### 4. Fatigue Conditions

Net stress: 30 ksi  
Test load: 8,590 lbs.  
Load ratio: (R) = 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophore (36 KIP)

Coldworked Good Drilled Hole  
Open

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-6	1	.3545	.3665	.3730	45	20	30	.0185	.0120	261	 C/W
	2	.3545	.3665	.3730	-	-	-	.0185	.0120		
-7	1	.3545	.3665	.3730	45	20	35	.0185	.0120	491	 C/W
	2	.3545	.3665	.3730	-	-	-	.0185	.0120		
-8	1	.3545	.3665	.3730	50	25	40	.0185	.0120	226	 C/W
	2	.3545	.3665	.3730	-	-	-	.0185	.0120		

[ ] > Taken at Minimum (not used)

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 A 3

NOMINAL EXPANSION VALUE: 0.0185"

## GENERAL TEST CONDITIONS

DATE: 4-19-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 2  
Width: 1.50"  
Hole spacing: 1.50"  
Edge margin: 0.75"  
Material: 2024 T 851  
Material gauge: 0.250"  
Surface Treatment: Shot Peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.010"  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM- 12 -0-N  
CW Mandrel Taper: 0.045"/"  
CW Mandrel Major Dia.: .353"  
Lubrication: Fel Pro 300 (on sleeve)








### 2. Hole Preparation

Nominal hole size: 3/8"  
Process: \*Drill , CW & ream  
\* Abusively Drilled

### 4. Fatigue Conditions

Net stress: 30 ksi  
Test load: 8,550 lbs.  
Load ratio: (R) = 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophone (36 KIP)

Coldworked Abusively Drilled  
Open

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before 	After 	After ream	Before 	After 	After Ream				
-9	1	.3545	.3670	.3730	120	45	30	.0185	.0125	110	 C/W
	2	.3545	.3670	.3730	-	-	-	.0185	.0125		
-10	1	.3545	.3670	.3730	125	40	35	.0185	.0125	287	 C/W
	2	.3545	.3670	.3730	-	-	-	.0185	.0125		
-11	1	.3545	.3670	.3730	145	35	30	.0185	.0125	93	 C/W
	2	.3545	.3670	.3730	-	-	-	.0185	.0125		



Taken at Minimum (midpoint)



Hole Bell Mouthed



Spiral Gauge In Hole

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 A 4

NOMINAL EXPANSION VALUE: 0.019"

## GENERAL TEST CONDITIONS

DATE: 3-27-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: .3730"  
 Lubrication: Fel Pro 300 (on sleeve)




### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: ream, CW

### 4. Fatigue Conditions

Net stress: 30 ksi +  
 Test load: 8,580 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/m inute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 KIP)

No Postream  
 Open Hole

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After ream	Before CW	After CW	After Ream				
-24	1	.3545	.3665	-	35	15	-	.0185	.0120	431	
	2	.3545	.3665	-	-	-	-	.0185	.0120		
-25	1	.3545	.3665	-	30	15	-	.0185	.0120	333	
	2	.3545	.3665	-	-	-	-	.0185	.0120		
-26	1	.3540	.3665	-	35	20	-	.0190	.0125	330	
	2	.3540	.3665	-	-	-	-	.0190	.0125		

1. Taken at Maximum (only one)

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 A 5

NOMINAL EXPANSION VALUE: 0.019"

## GENERAL TEST CONDITIONS

DATE: 3-28-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig 2  
Width: 1.50"  
Hole spacing: 1.50"  
Edge margin: 0.75"  
Material: 2024 T 851  
Material gauge: 0.250"  
Surface Treatment: Shot Peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.010"  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM-12 -0-N  
CW Mandrel Taper: 0.045"/"  
CW Mandrel Major Dia.: .3530"  
Lubrication: Fel Pro 300 (on sleeve)

### 2. Hole Preparation





Nominal hole size: 3/8"  
Process: Ream, C/W, Ream & Score \*  
\* 90° to  $Q_c$

### 4. Fatigue Conditions

Net stress: 30 ksi +  
Test load: 8,500 lbs.  
Load ratio: (R) = 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophore (36 KIP)

Postscore One Hole  
Open

Black fretting products from reaming in all holes and fatigue fracture

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-27	1	.3540	.3665	.3730	40	25	45	.0190	.0125	300	 C/W Failure in Unscored Hole
	2	.3545	.3665	.3730	-	-	-	.0185	.0120		
-28	1	.3545	.3665	.3730	35	15	50	.0185	.0120	∞	 C/W Failure in Unscored Hole
	2	.3545	.3665	.3730	-	-	-	.0185	.0120		
-29	1	.3545	.3665	.3730	40	20	45	.0185	.0120	393	 C/W Failure in Unscored Hole
	2	.3545	.3665	.3730	-	-	-	.0185	.0120		

1 - Taken at Minimum (midpoint)

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 A 6

NOMINAL EXPANSION VALUE: 0.019"

## GENERAL TEST CONDITIONS

DATE: 3-28-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 2  
Width: 1.50"  
Hole spacing: 1.50"  
Edge margin: 0.75"  
Material: 2024 T 851  
Material gauge: 0.250"  
Surface Treatment: Shot Peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.010"  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM- 12 -0-N  
CW Mandrel Taper: 0.045"/"  
CW Mandrel Major Dia.: 3530"  
Lubrication: Fel Pro 300 (on sleeve)





### 2. Hole Preparation


Nominal hole size: 3/8"  
Process: Ream, C/W & Ream (full 1/64")

Full 1/64" Postream  
Open Hole

### 4. Fatigue Conditions

Net stress: 30 ksi  
Test load: 8,450 lbs.  
Load ratio: (R) = 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophore (36 KIP)

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-30	1	.3545	.3665	.3895	35	15	-	.0185	.0120	235	 C/W
	2	.3545	.3665	.3895	-	-	-	.0185	.0120		
-31	1	.3545	.3665	.3895	40	20	35	.0185	.0120	249	 C/W
	2	.3545	.3665	.3895	-	-	-	.0185	.0120		
-32	1	.3545	.3665	.3895	45	20	30	.0185	.0120	214	 C/W
	2	.3545	.3665	.3895	-	-	-	.0185	.0120		

 Taken at Minimum (midpoint)

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 A 7

NOMINAL EXPANSION VALUE: 0.019"

## GENERAL TEST CONDITIONS

DATE: 3-28-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 2  
Width: 1.50"  
Hole spacing: 1.50"  
Edge margin: 0.75"  
Material: 2024 T 851  
Material gauge: 0.250"  
Surface Treatment: Shot Peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.010"  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM-12 -G-N  
CW Mandrel Taper: 0.045"/"  
CW Mandrel Major Dia.: .3530"  
Lubrication: Fel Pro 300 (on sleeve)




### 2. Hole Preparation

Nominal hole size: 3/8"  
Process: Ream, C/W, Ream 1/32 os

1/32" Postream  
Open Hole

### 4. Fatigue Conditions

Net stress: 30 ksi  
Test load: 8,270 lbs.  
Load ratio: (R) 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophone (36 KIP)

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After ream	Before CW	After CW	After Ream				
-33	1	.3545	.3665	.4075	50	20	55	.0185	.0120	283	 C/W
	2	.3545	.3665	.4075	-	-	-	.0185	.0120		
-34	1	.3545	.3665	.4075	45	20	45	.0185	.0120	256	 C/W
	2	.3545	.3665	.4075	-	-	-	.0185	.0120		
-35	1	.3545	.3665	.4075	35	15	40	.0185	.0120	285	 C/W
	2	.3545	.3665	.4075	-	-	-	.0185	.0120		

 Taken at Minimum (midpoint)

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 A B

NOMINAL EXPANSION VALUE: 0.019"

## GENERAL TEST CONDITIONS

DATE: 3-28-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig 2  
Width: 1.50"  
Hole spacing: 1.50"  
Edge margin: 0.75"  
Material: 2024 T 851  
Material gauge: 0.250"  
Surface Treatment: Shot Peen  
Fastener: None

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.010"  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM- 12 -0-N  
CW Mandrel Taper: 0.045"/"  
CW Mandrel Major Dia.: .3730"  
Lubrication: Fel Pro 300 (on sleeve)





### 2. Hole Preparation


Nominal hole size: 3/8" + 1/16"  
Process: Ream, C/W, Ream 1/16 as

### 4. Fatigue Conditions

Net stress: 30 ksi  
Test load: 8,000 lbs.  
Load ratio: (R) 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophore (36 KIP)

1/16" Postream  
Open Hole

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
36	1	.3545	.3665	.4375	30	15	25	.0185	.0120	312	 Reamer C/W Chatter
	2	.3545	.3665	.4375	-	-	-	.0185	.0120		
37	1	.3545	.3665	.4375	35	15	25	.0185	.0120	372	 Reamer C/W Chatter
	2	.3545	.3665	.4375	-	-	-	.0185	.0120		
38	1	.3545	.3665	.4375	30	15	30	.0185	.0120	226	 Reamer C/W Chatter
	2	.3545	.3665	.4375	-	-	-	.0185	.0120		

 Taken at Minimum (midpoint)

## PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 A 9

NOMINAL EXPANSION VALUE: 0.019"

## GENERAL TEST CONDITIONS

DATE: 3-29-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK

Configuration: Fig. 2

Width: 1.50"

Hole spacing: 1.50"

Edge margin: 0.75"

Material: 2024 T 851

Material gauge: 0.250"

Surface Treatment: Shot Peen

Fortener: None

## 2. Hole Preparation

Nominal hole size: 3/8"

Process:

Sq. Wire Sleeve  
Open Hole

### 3. CW Process

Sleeve type: Square Wire

Sleeve thickness: 0.018"

Sleeve orientation: 0°

CW Mandrel: ST 5300-CBM- -0-N

CW Mandrel Taper: 0.045"/"

CW Mandrel Major Dia.: .3530"

Lubrication: Fel Pro 300 (on sleeve)

#### 4. Fatigue Conditions

Net stress: 30 ksi †

Test load: 8,400 lbs.

Load ratio:  $\frac{P}{(R)} = 0.1$

Test Frequency: 5000/minute

Test Laboratory: Materials






Test Engineer: D. Reese

Test Machine: Vibrophore (36 KIP)

\*Trouble encountered with wire sleeve

C/W one hole twice - Gouge In Test

Section + Mark In Hole

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
12	1	.3690	.3800	.3895	35	-	40	.0200	.0110	167	 C/W
	2	.3690	.3800	.3895	-	-	-	.0200	.0110		
13	1	.3690	.3800	.3895	30	-	30	.0200	.0110	339	 C/W
	2	.3690	.3800	.3895	-	-	-	.0200	.0110		
14	1	.3690	.3805	.3895	35	-	40	.0200	.0115	586	 C/W
	2	.3690	.3800	.3895	-	-	-	.0200	.0110		

1. 1.4 cu. of *Aspidium* (moss) (10.1)

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 481

NOMINAL EXPANSION VALUE: 0.019"

## GENERAL TEST CONDITIONS

DATE: 3-27-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.060"  
 Surface Treatment: Shot Peen  
 Fastener: None

### 2. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: .3730"  
 Lubrication: Fel Pro 300 (on sleeve)




### 3. Hole Preparation

Nominal hole size: 3/8"  
 Process: Drill, ream, CW & ream

### 4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 2,150 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 3500/minute  
 Test Laboratory: Materials  
 Test Engineer: D Reese  
 Test Machine: Vibrophore (36 Kip)

.060 Gage  
 Open Hole

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 1	After ream	Before CW	After CW	After Ream				
-1	1	.3540	.3665	.3735	40	20	30	.0190	.0125	48	 CW
	2	.3540	.3665	.3735	-	-	-	.0190	.0125		
-2	1	.3540	.3665	.3735	40	20	25	.0190	.0125	49	 CW
	2	.3540	.3665	.3735	-	-	-	.0190	.0125		
-3	1	.3540	.3665	.3735	40	20	30	.0190	.0125	65	 CW
	2	.3540	.3665	.3735	-	-	-	.0190	.0125		

1 Taken at Minimum (midpoint)

PHASE II TASK 4 - APPLICATION OF PHASE II PROCEDURES

TEST NUMBER: 4 C 1

NOMINAL EXPANSION VALUE: 0.019 (One Hole)

GENERAL TEST CONDITIONS

DATE: 3-30-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig 2  
Width: 1.50"  
Hole spacing: 1.50"  
Edge margin: 0.75"  
Material: 2024 T851  
Material gauge: 0.250"  
Surface Treatment: Shot Peen  
Fastener: Prot Hd. HI-Lot

3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.010"  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM 12 (0-N)  
CW Mandrel Taper: 0.045"/"  
CW Mandrel Major Dia: .3530  
Lubrication: Fel Pro 300 (on sleeve)





2. Hole Preparation

Nominal hole size: 3/8"  
Process: 1. Ream C/W, Ream & Install Fastener  
2. Ream and Install Fastener  
Fastener Instl. Torque: 225-250 in/lbs  
Fastener Diameter: .3735

4. Fatigue Conditions

Net stress: 30 ksi  
Test load: 8,550/lbs  
Load ratio: (R) 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophore (36 Kip)

One Hole Not C/W  
Filled Holes

Specimen No., R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-57	1	.3545	.3665	.3735	40	20	25	.0185	.0125	855	 failure at non-coldworked hole
	2	-	-	.3735	-	-	-	-	-		
-58	1	.3540	.3660	.3735	30	15	30	.0190	.0120	703	 failure through coldworked hole
	2	-	-	.3735	-	-	-	-	-		
-59	1	.3540	.3665	.3735	35	15	30	.0190	.0125	375	 failure at non-coldworked hole
	2	-	-	.3735	-	-	-	-	-		

 Taken at Minimum (midpoint)

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 C 2

NOMINAL EXPANSION VALUE: 0.019"

## GENERAL TEST CONDITIONS

DATE: 3-30-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Prot. Hd. Hi-Lok  
(.002 Clearance Fit)

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: .3530  
 Lubrication: Fel Pro 300 (on sleeve)

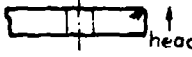


### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, C/W & ream  
 Fastener Torque: 225/250 in/lbs  
 Fastener Diameter: .3735

### 4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8.550 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

.002" CL. Hi-Lok  
Hole C/W

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After ream	Before CW	After CW	After Ream				
-42	1	.3540	.3665	.3755	35	15	30	.0190	.0125	694	
	2	.3540	.3665	.3755	-	-	-	.0190	.0125		
-43	1	.3540	.3665	.3755	30	15	25	.0190	.0125	366	
	2	.3540	.3665	.3755	-	-	-	.0190	.0125		
-44	1	.3540	.3665	.3755	30	15	30	.0190	.0125	697	
	2	.3540	.3665	.3755	-	-	-	.0190	.0125		

 Taken at Minimum (midpoint)

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 C 3

NOMINAL EXPANSION VALUE: 0.019"

## GENERAL TEST CONDITIONS

DATE: 4-16-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: HI-Lok (.002" interference)

### 3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-T2 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: .353"  
 Lubrication: Fel Pro 300 (on sleeve)



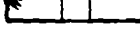
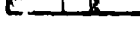
### 2. Hole Preparation

Nominal hole size: 3/8"  
 Process: ream, CW & ream  
 Fastener Diameter: .3535  
 Fastener Inst'l Torque: 225/250 In/lb.

C/W .002  
 Interference HI-Lok

### 4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,630 lbs.  
 Load ratio: (R) 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

Specimen No. K623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-45	1	.3540	.3665	.3710	35	15	30	.0190	.0125	120	 head
	2	.3540	.3665	.3710	-	-	-	.0190	.0125		
-46	1	.3540	.3665	.3710	40	20	25	.0190	.0125	185	 head
	2	.3540	.3665	.3710	-	-	-	.0190	.0125		
-47	1	.3540	.3665	.3710	30	15	30	.0190	.0125	258	 head
	2	.3540	.3665	.3710	-	-	-	.0190	.0125		

 Taken at Minimum (midpoint)

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 C 4  
 NOMINAL EXPANSION VALUE: 0.019"

## GENERAL TEST CONDITIONS

DATE: 4-2-73

### 1. Specimen Description

Zero load transfer, 2 hole CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hi-Lok 100 Hd., Net Fit

### 2. Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: .353  
 Lubrication: Fel Pro 300 (on sleeve)


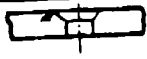
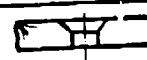

### 3. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, C/W, Ream & CSK  
 Fastener Diameter: .3538-.3540  
 Fastener Inst'l Torque: 225/250 in./lbs

100° CSK after C/W  
 Net Fit Hi-Lok

### 4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,600 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5,000  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-48	1	.3540	.3665	.3735	35	15	30	.0190	.0125	1,247	
	2	.3540	.3665	.3735	-	-	-	.0190	.0125		
-49	1	.3540	.3665	.3735	40	20	45	.0190	.0125	950	
	2	.3540	.3665	.3735	-	-	-	.0190	.0125		
-50	1	.3540	.3665	.3540	40	20	35	.0190	.0125	1,186	
	2	.3540	.3665	.3540	-	-	-	.0190	.0125		

 Taken at Minimum (midpoint)

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 C 5

NOMINAL EXPANSION VALUE: 0.019"

GENERAL TEST CONDITIONS

DATE: 4-2-73

1. Specimen Description

Zero load transfer, 2 hole, CSK  
Configuration: Fig 2  
Width: 1.50"  
Hole spacing: 1.50"  
Edge margin: 0.75"  
Material: 2024 T851  
Material gauge: 0.250"  
Surface Treatment: Shot Peen  
Fastener: Hi-Lok 100° HD, Net Fit

3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.010"  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM- 12 -0-N  
CW Mandrel Taper: 0.045"/"  
CW Mandrel Major Dia.: .353"  
Lubrication: Fel Pro 300 (on sleeve)


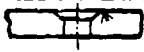


2. Hole Preparation

Nominal hole size: 3/8"  
Process: Ream, CSK, C/W, Ream  
Fastener Diameter: .3740  
Fastener Inst'l Torque: 225/250 in/lbs

4. Fatigue Conditions

Net stress: 301 ksi  
Test load: 8,550 lbs.  
Load ratio: (R) = 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophore (36 Kip)

100° CSK Before C/W  
Net Fit Hi-Lok

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-51	1	.3540	.3665	.3740	25	15	40	.0190	.0125	169	
	2	.3540	.3665	.3740	-	-	-	.0190	.0125		
-52	1	.3540	.3665	.3740	30	15	40	.0190	.0125	508	
	2	.3540	.3665	.3740	-	-	-	.0190	.0125		
-53	1	.3540	.3665	.3740	30	15	45	.0190	.0125	213	
	2	.3540	.3665	.3740	-	-	-	.0190	.0125		

 Taken at Minimum (midpoint)

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4C 6

NOMINAL EXPANSION VALUE: .0185

## GENERAL TEST CONDITIONS

DATE: 4-16-73

### 1. Specimen Description

Zero load transfer, 2 hole  
Configuration: Fig. 2  
Width: 1.50"  
Hole spacing: 1.50"  
Edge margin: 0.75"  
Material: 2024 T851  
Material gauge: 0.250"  
Surface Treatment: Shot Peen  
Fastener: HI-Lok with 70° head

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.010"  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM- 12 -0-N  
CW Mandrel Taper: 0.045"/"  
CW Mandrel Major Dia.: .3530  
Lubrication: Fel Pro 300 (on sleeve)





### 2. Hole Preparation

Nominal hole size: 3/8"  
Process: Drill, ream, CW & ream, CSK  
Fastener Diameter: .3800"  
Fastener Inst'l Torque: 225/250"/in.lb.  
Fastener Flt: Net

### 4. Fatigue Conditions

Net stress: 30 ksi  
Test load: 8,550 lbs.  
Load ratio: (R) = 0.1  
Test Frequency: 5,000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophore (36 Kip)

70° CSK after C/W  
Net Flt HI-Lok

Specimen No. 2623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-54	1	.3545	.3665	.3800	40	20	35	.0185	.0120	290	
	2	.3545	.3665	.3800	-	-	-	.0185	.0120		
-55	1	.3545	.3665	.3800	35	15	40	.0185	.0120	315	
	2	.3545	.3665	.3800	-	-	-	.0185	.0120		
-56	1	.3545	.3665	.3800	40	20	35	.0185	.0120	191	
	2	.3545	.3665	.3800	-	-	-	.0185	.0120		

 Taken at Minimum (midpoint)

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 C 7

NOMINAL EXPANSION VALUE: 0.019

## GENERAL TEST CONDITIONS

DATE: 4-25-73

### 1. Specimen Description

Zero load transfer, 2 hole, no CSK  
Configuration: Fig. 2  
Width: 1.50"  
Hole spacing: 1.50"  
Edge margin: 0.75"  
Material: 2024 T851  
Material gauge: 0.250"  
Surface Treatment: Shot Peen  
Fastener: Prot. Hd. Nut Flt HI-Lok

### 3. CW Process

Sleeve type: Axial Split  
Sleeve thickness: 0.010"  
Sleeve orientation: 0°  
CW Mandrel: ST 5300-CBM-12 -0-N  
CW Mandrel Taper: 0.045"/"  
CW Mandrel Major Dia.: .3530  
Lubrication: Fel Pro 300 (on sleeve)





### 2. Hole Preparation

Nominal hole size: 3/8"  
Process: 1. Ream.  
2. Install under-size fastener

Reamed only with HI-Lok  
Test at 30 ksi

### 4. Fatigue Conditions

Net stress: 30 ksi  
Test load: 8,750 lbs.  
Load ratio: (R) = 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophore (36 Kip)

Specimen No. R623080	Hole No.	Hole Diameter (Inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-15	1	-	-	.3430	-	-	-	-	-	172	
	2	-	-	.3430	-	-	-	-	-		
-16	1	-	-	.3430	-	-	-	-	-	200	
	2	-	-	.3430	-	-	-	-	-		
-17	1	-	-	.3430	-	-	-	-	-	222	
	2	-	-	.3430	-	-	-	-	-		

 Taken at Minimum (midpoint) Test engineer did not stop at 80,000 cycles

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 C 8

NOMINAL EXPANSION VALUE: 0.019"

Precracked and C/W  
net-fit HI-Lok  
30 ksi

## GENERAL TEST CONDITIONS:

DATE: 4-3-73

### 1. Specimen Description

Zero load transfer, 2 holes, no CSK  
Configuration: Fig. 2  
Width: 1.50"  
Hole spacing: 1.50"  
Edge margin: 0.75"  
Material: 2024 T851  
Material gauge: 0.250"  
Surface Treatment: Shot Peen  
Fastener: Net fit - HI-Lok

### 3. C/W Process

Sleeve type: Avial  
Sleeve thickness: 0.010"  
Sleeve orientation: 0°  
CW Mandrel: ST 5200-CBM-12 -0-N  
CW Mandrel Taper: 0.045"/"  
CW Mandrel Major Dia.: .353"  
Lubrication: Fel-Pro 300 (on sleeve)

### 2. Hole Preparation

Nominal hole size: 3/8"

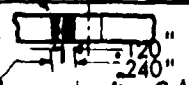

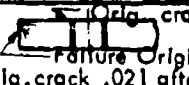
Process: 1. Pilot Drill

2. Notch (fatigue crack to length to give .030" crack length at pre C/W ream dia. (at 30 ksi)
3. Ream
4. C/W
5. Ream
6. Install net fit HI-Lok


### 4. Fatigue Conditions

Net stress: 30 ksi  
Test load: 8,650 lbs.  
Load ratio: (R) 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophore (36 Kip)

.030 ± .005" crack after C/W ream  
.3540 diameter

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After ream	Before CW	After CW	After Ream				
-18	1	.3540	.3670	.3735	40	20	45	.0190	.0130	30 to crack 93 after C/W	 123 total Orig. crack after C/W and postream
	2	.3540	.3670	.3735	-	-	-	.0190	.0130		
-19	1	.3540	.3670	.3735	40	20	50	.0190	.0130	32 to crack 515 aft CW	 547 total Orig. crack at hole .021 aft. C/W & postream
	2	.3540	.3670	.3735	-	-	-	.0190	.0130		
-20	1	.3540	.3670	.3735	35	15	55	.0190	.0130	18 to crack 607 aft. CW	 625 total Orig. crack .021 after C/W & postream
	2	.3540	.3670	.3735	-	-	-	.0190	.0130		

 Taken at Minimum (midpoint)  
 Pilot Hole Dia. = .3155"

 -18 (30,000 cycles - .050 crack) -19 & -20  
 .050" crack (gives .030" at .354" diameter)

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER 4 D 1 (Edge Margin) (Open Holes)  
 NOMINAL EXPANSION VALUE: 0.019 Inch

GENERAL TEST CONDITIONS

DATE: \_\_\_\_\_

1. Specimen Description

Edge Margin - 4 Hole, No CSK  
 Configuration: Fig. 7a  
 Width: 3.124  
 Hole spacing: 1.50" x 2.00"  
 Edge Margin: .562  
 Material: 2024-T851  
 Material Gage: 0.025 Inch  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve Type: Split  
 Sleeve orientation: 0°




2. Hole Preparation

Nominal Hole Size: 3/8 Inch  
 Process: Ream, Coldwork, Ream

4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 18,115 lbs  
 Load Ratio: R= 0.1  
 Tes. Frequency: 5000/Min.  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 KIP)

1-1/2D E/M  
 C/W open hole  
 30 ksi

Specimen No. R623080	Hole No.	Hole Diameter (Inches)			Hole Finish (RHR) Final Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After Ream			
-89	1	.3540	.3665	.3735	35	359	 CW
	2	.3542	.3665	.3735	-		
	3	.3542	.3665	.3735	35		
	4	.3544	.3665	.3735	-		
-90	1	.3545	.3665	.3735	40	215	 CW
	2	.3545	.3666	.3735	-		
	3	.3545	.3666	.3735	45		
	4	.3545	.3668	.3735	-		
-91	1	.3545	.3666	.3735	40	183	 CW
	2	.3544	.3666	.3735	-		
	3	.3544	.3664	.3735	35		
	4	.3545	.3667	.3735	-		

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER 4 D 2 (Edge Margin) (Open Holes)  
 NOMINAL EXPANSION VALUE: 0.019 Inch

## GENERAL TEST CONDITIONS

DATE: \_\_\_\_\_

### 1. Specimen Description

Edge Margin - 4 Hole, No CSK  
 Configuration: Fig 7b  
 Width: 3.50"  
 Hole spacing: 1.50" x 2.00"  
 Edge Margin: .750"  
 Material: 2024-T851  
 Material Gage: 0.025 Inch  
 Surface Treatment: Shot Peen  
 Fastener: None

### 3. CW Process

Sleeve Type: Split  
 Sleeve orientation: 0°

### 2. Hole Preparation

Nominal Hole Size: 3/8 Inch  
 Process: Ream, Coldwork, Ream

### 4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 20,860 lbs  
 Load Ratio: R= 0.1  
 Test Frequency: 5000/Min.  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 KIP)

2D E/M  
 C/W open hole  
 30 ksi

Specimen No. R623080	Hole No.	Hole Diameter (Inches)			Hole Finish (RHR) Final Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After Ream			
-93	1	.3540	.3667	.3735	35	504	
	2	.3542	.3666	.3735	-		
	3	.3544	.3666	.3735	-		
	4	.3543	.3665	.3735	35		
-94	1	.3544	.3667	.3735	35	535	
	2	.3535	.3667	.3735	-		
	3	.3542	.3668	.3735	40		
	4	.3542	.3667	.3735	35		
-95	1	.3543	.3667	.3735	40	253	
	2	.3542	.3668	.3735	35		
	3	.3544	.3667	.3735	40		
	4	.3543	.3667	.3735	35		

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER 4 D 3 (Edge Margin) (Open Holes)  
 NOMINAL EXPANSION VALUE: 0.019 Inch

## GENERAL TEST CONDITIONS

DATE: \_\_\_\_\_

### 1. Specimen Description

Edge Margin - 4 Hole, No CSK  
 Configuration: Fig 7C  
 Width: 3.874  
 Hole spacing: 1.50" x 2.00"  
 Edge Margin: .937  
 Material: 2024-T851  
 Material Gage: 0.025 Inch  
 Surface Treatment: Shot Peen  
 Fastener: None

### 3. CW Process

Sleeve Type: Split  
 Sleeve orientation: 0°




### 2. Hole Preparation

Nominal Hole Size: 3/8 Inch  
 Process: Ream, Coldwork, Ream

### 4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 23,725 lbs  
 Load Ratio: R= 0.1  
 Test Frequency: 5000/Min.  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 KIP)

2:1:2D E/M  
 C/W open hole  
 30 ksi

Specimen No. R623080	Hole No.	Hole Diameter (Inches)			Hole Finish (RHR) Final Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After Ream			
-97	1	.3542	.3670	.3735	40	756	
	2	.3542	.3673	.3735	-		
	3	.3542	.3670	.3735	-		
	4	.3542	.3670	.3730	35		
-98	1	.3543	.3669	.3735	35	393	
	2	.3545	.3669	.3735	-		
	3	.3542	.3669	.3735	-		
	4	.3543	.3673	.3735	35		
-99	1	.3544	.3673	.3735	40	254	
	2	.3543	.3670	.3740	35		
	3	.3544	.3672	.3735	35		
	4	.3544	.3672	.3735	35		

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER 4 D 4 (Edge Margin) (Open Holes)  
 NOMINAL EXPANSION VALUE: 0.019 Inch

## GENERAL TEST CONDITIONS

DATE: \_\_\_\_\_

### 1. Specimen Description

Edge Margin - 4 Hole, No CSK  
 Configuration: Fig 7d  
 Width: 2.994  
 Hole spacing: 1.50" x 1.12"  
 Edge Margin: .9.37  
 Material: 2024-T851  
 Material Gage: 0.025 Inch  
 Surface Treatment: Shot Peen  
 Fastener: None

### 3. CW Process

Sleeve Type: Split  
 Sleeve orientation: 0°




### 2. Hole Preparation

Nominal Hole Size: 3/8 Inch  
 Process: Ream, Coldwork, Ream

### 4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 17,330 lbs  
 Load Ratio: R = 0.1  
 Test Frequency: 5000/Min.  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 KIP)

3D hole spacing  
 C/W open hole  
 30 ksi

Specimen No. R623080	Hole No.	Hole Diameter (Inches)			Hole Finish (RHR) Final Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After Ream			
-101	1	.3545	.3665	.3535	35	339	
	2	.3544	.3665	.3535	-		
	3	.3544	.3665	.3535	-		
	4	.3544	.3665	.3535	35		
-102	1	.3543	.3665	.3535	35	355	 Crack occurred between holes
	2	.3540	.3665	.3535	40		
	3	.3542	.3665	.3535	40		
	4	.3542	.3665	.3535	35		
-103	1	.3540	.3666	.3535	40	380	
	2	.3542	.3665	.3535	-		
	3	.3542	.3665	.3535	-		
	4	.3539	.3665	.3535	40		

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER 4 D 5 (Edge Margin) (Open Holes)  
 NOMINAL EXPANSION VALUE: 0.019 Inch

## GENERAL TEST CONDITIONS

DATE: \_\_\_\_\_

### 1. Specimen Description

Edge Margin - 4 Hole, No CSK  
 Configuration: Fig. 7c  
 Width: 3.374  
 Hole spacing: 1.50" x 1.50"  
 Edge Margin: .937  
 Material: 2024-T851  
 Material Gage: 0.025 Inch  
 Surface Treatment: Shot Peen  
 Fastener: None

### 3. CW Process

Sleeve Type: Split  
 Sleeve orientation: 0°




### 2. Hole Preparation

Nominal Hole Size: 3/8 Inch  
 Process: Ream, Coldwork, Ream

### 4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 19,900 lbs  
 Load Ratio: R= 0.1  
 Test Frequency: 5000/Min.  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 KIP)

40 hole spacing  
 CW open hole  
 30 ksi

Specimen No. R623080	Hole No.	Hole Diameter (Inches)			Hole Finish (RHR) Final Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After Ream			
-105	1	.3543	.3665	.3735	40	300	 CW
	2	.3543	.3666	.3735	-		
	3	.3542	.3666	.3735	40		
	4	.3542	.3666	.3735	-		
-106	1	.3544	.3670	.3735	40	294	 CW
	2	.3543	.3670	.3735	-		
	3	.3543	.3670	.3735	35		
	4	.3543	.3670	.3735	40		
-107	1	.3543	.3670	.3735	35	272	 CW
	2	.3542	.3670	.3735	40		
	3	.3543	.3670	.3735	40		
	4	.3543	.3670	.3735	35		

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

2024, 15-Hole, Single, C/W, Filled

TEST E1 SPECIMEN 623080 DATE 5/9/73

2024  
15-hole single coupon  
C/W filled for Hi Lok

## SPECIMEN DESCRIPTION

Configuration	F-g 9
Material	2024-T851
Width (in.)	1.00
Hole spacing	1.00
Edge margin (in.)	0.50
Material gauge (in.)	0.250
Surface treatment	Shot peen

## COLDWORK PROCESS

Interference (in.)	0.014/0.015
Sleeve type	Split
Sleeve thickness (in.)	0.008
Sleeve orientation	0°
Mandrel material	H 11 steel
Mandrel taper (in./in.)	0.015
Mandrel max diameter (in.)	0.2300
Lubrication	Fel Pro

## HOLE PREPARATION

Nominal hole size (in.)	1/4
Process	Ream, C/W ream
FASTENER INSTALLATION	
Type	Hi Lok 1/4 in. prot hd
Fit	Nut
Torque (in. lb)	80 (stringer only)

## FATIGUE CONDITIONS

Max test stress (ksi)	40
Max test load (lbf)	7500
Load ratio (R)	0.1
Test frequency	600 cpm
Test laboratory	Materials
Test engineer	D Reese
Test machine	Riehle Los

Specimen dash no.	Hole no (a)	Hole diameter (in.)			Hole finish (RH4)			Control's expansion (in.)		Fastener location		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After ream	After coldwork	A 1-1/2"	H 1-1/2"	Diameter	F 1		
83	1	0.2310		0.2485				20	0.015			149,850	
	2												
	3												
	4												
84	1	0.2310		0.2485				25	0.015			150,320	
	2												
	3												
	4												
85	1	0.2310		0.2485				20	0.015			135,990	
	2												
	3												
	4												

a Typical hole measurement

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

2024, 15-Hole, Dual, C/W, Filled, One At Time

TEST: F1 SPECIMEN: 623080 DATE: 5/9/73

2024  
15 hole dual coupon  
C/W and filled one  
at time (net-fit)

## SPECIMEN DESCRIPTION

Configuration: Fig. 8  
Material: 2024-T851  
Width (in.): Skin-2.50; stringer-1.00  
Rise: 1.00  
Edge margin (in.): Skin-1.25; stringer-0.50  
Mate at gaps (in.): 0.250  
Surface treatment: Shot peen

## COLDWORK PROCESS

Interference (in.): 0.014/0.015  
Sleeve type: Split  
Sleeve thickness (in.): 0.008  
Sleeve orientation: 0°  
Mandrel material: H-11 steel  
Mandrel taper (in./in.): 0.015  
Mandrel max diameter (in.): 0.2300

## HOLE PREPARATION

Nominal hole size (in.): 1/4  
Process: Ream, C/W, ream

## FATIGUE CONDITIONS

Max net stress (ksi): 30  
Max test load (lbf): 22.7  
Load ratio (R): 0.1  
Test frequency: 600 cpm  
Test laboratory: Materials  
Test engineer: D. Reese  
Test machine: Riehle-Los

## FASTENER INSTALLATION

Type: Hi-Lok, 1/4-in. prot hd  
Fit: Net

Torque (in. lb): 80 (fasteners installed one at a time)

Specimen ID	Hole No. (a)	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
-86	1	0.2310		0.2485			15	0.015				265,000	C/W Hd Hole 4
	2												Fretting evident on surfaces C/W Hd Hole 8
	3												Fretting on surface C/W Hd Hole 3
	4												Fretting on surface
-87	1	0.2310		0.2485			20	0.015				264,000	C/W Hd Hole 4
	2												Fretting evident on surfaces C/W Hd Hole 8
	3												Fretting on surface C/W Hd Hole 3
	4												Fretting on surface
-88	1	0.2310		0.2485			15	0.015				288,000	C/W Hd Hole 4
	2												Fretting evident on surfaces C/W Hd Hole 8
	3												Fretting on surface C/W Hd Hole 3
	4												Fretting on surface

a Typical hole measurement

**PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS**

2024  
15-hole dual coupon  
C/W and filled,  
production technique

TEST F2 SPECIMEN 623080 DATE 5/9/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. B	Interference (in.)	0.014/0.015	Nominal hole size (in.)	1/4	Max. net stress (ksi)	89, 90-40 91-30
Material	2024-T851	Sleeve type	Split	Process	Ream, C/W, ream	Max test load (kpl)	Gross-26.1 Net-22.6
Width (in.)	Skin-2.50, stringer-1.00	Sleeve thickness (in.)	0.008			Load ratio (R)	0.1
Hole spacing	1.00	Sleeve orientation	0°			Test frequency	600 cpm
Edge margin (in.)	Skin-1.25; stringer-0.50	Mandrel material	H-11 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)	0.015	Type	Hi-Lok 1/4-in. prot hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.2300	Fit (in.)	0.0015	Test machine	Riehle-Lo
		Lubrication	Fel Pro	Torque (in.-lb)		80 (middle; two end fasteners installed first, then the rest)	

Specimen dash no.	Hole no. (a)	Hole diameter (in.)		Hole finish (RHRI)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
-89	1	0.2310	0.2485		15	0.015			(b)	153,000	Stringer-hole 3 C/W ↑ Hd ↑ Fretting on surfaces
	2										
	3										
	4										
-90	1	0.2310	0.2485		25	0.015			(b)	146,000	Skin-hole 2 C/W ↑ Hd ↑ Fretting on surfaces
	2										
	3										
	4										
-91	1	0.2310	0.2485		25	0.015			(c)	273,900	Hole 4 C/W ↑ Hd ↑ Fretting on surfaces
	2										
	3										
	4										

a Typical hole measurement      b Gross stress      c Net stress

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

2024, 15-Hole, Dual, C/W, Filled, No Postream

TEST F3 SPECIMEN 623080 DATE 6/22/73

2024  
15 hole dual coupon  
C/W - filled,  
no postream

## SPECIMEN DESCRIPTION

Fig. 8  
2024-T851  
Skin-2.50; stringer-1.00  
1.00  
Hole spacing  
Skin-1.25; stringer-0.50  
Mandrel material  
H-11 steel  
0.015  
Mandrel taper (in./in.)  
0.2380  
Mandrel max diameter (in.)  
0.2380  
Surface treatment  
Shot peen

## COLDWORK PROCESS

Interference (in.)  
0.014/0.015  
Split  
Sleeve type  
0.008  
Sleeve thickness (in.)  
0  
Sleeve orientation  
H-11 steel  
0.015  
Mandrel taper (in./in.)  
0.2380  
Mandrel max diameter (in.)  
0.2380  
Lubrication  
Fel Pro

## HOLE PREPARATION

Nominal hole size (in.)  
1/4  
Process  
Ream, C/W  
Type  
Hi-Lok 1/4-in. prot hd  
Fit  
Net  
Torque (in.-lb.)  
80

## FATIGUE CONDITIONS

Max net stress (ksi)  
40  
Max test load (kip)  
26.5  
Load ratio (R)  
0.1  
Test frequency  
600 cpm  
Test laboratory  
Materials  
Test engineer  
D. Reese  
Test machine  
Riehle-Los

Specimen dash no	Hole no (a)	Hole diameter (in.)		Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycl. to failure	Origin of failure and remarks
		Before coldwork	After ream	After coldwork	After ream	Before coldwork	Actual	Retained	Diameter	Fit		
-76	1	0.2390	0.2495		20						154,600	C/W Stringer-hole 3
	2											Hd
	3											Fretting both sides
	4											Stringer-hole 2
-77	1	0.2390	0.2495		25						157,200	C/W Stringer-hole 9
	2											Hd
	3											Fretting both sides
	4											Stringer-hole 10
b-78	1	0.2390	0.2495		20						165,500	C/W Hole 11
	2											Hd
	3											Fretting both sides
	4											Fretting both sides

<sup>a</sup>Typical hole measurement

<sup>b</sup>Hole spacing 1.3/8 in. versus 1 in. on -76 and -77

# PHASE II TASK 4 - APPLICATION AND FREQUENCY PARAMETERS

TEST NUMBER: 4 G 1

## GENERAL TEST CONDITIONS

DATE: 4-24-73

### 1. Specimen Description

High Load Transfer: Fig. 10  
 Material: 2024-T851  
 Material Gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hi-Lok, Prot. Head

### 3. Fastener Installation:

Fastener Fit: Net  
 Installation Torque: 225/250 in/lbs.


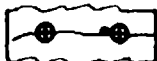


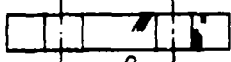
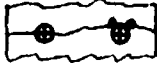
### 2. Hole Preparation

Nominal Hole Size: 3/8"  
 Process: Ream, C/W, Ream  
 CW Process: Sleeve  
 CW Interference: 0.0185"

### 4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 16,800 lbs  
 Load Ratio: R = 0.1  
 Test Frequency: 600 CPM  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Riehle-Los

C/W Net Fit P.H. HiLok  
 .010" Shim

Specimen No. R623080	Typical Hole Diameter Before CW (Inches)	Typical Final Hole Diameter (Inches)	Cycles to Failure	Origin of Failure and Remarks	LOAD
-109	.3545	.3730	580,620	 No Surface Fretting	
-110	.3545	.3730	371,350	 Origin at 45° to $\sigma$ No surface fretting	
-111	.3545	.3735	500,440	 Origin at 45° No surface fretting	

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 G 2

## GENERAL TEST CONDITIONS

DATE: 4-24-73

### 1. Specimen Description

High Load Transfer: Fig 10  
 Material: 2024 T851  
 Material Gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hi-Lok - Prot. Head

### 3. Fastener Installation:

Fastener Flt: .002" clearance  
 Installation Torque: 225/250 in/lbs



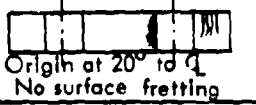

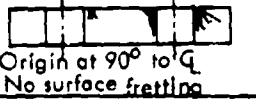

### 2. Hole Preparation

Nominal Hole Size: 3/8"  
 Process: Ream, C/W, ream  
 CW Process: Sleeve  
 CW Interference: 0.0185"

### 4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 16,800 lbs.  
 Load Ratio: R = 0.1  
 Test Frequency: 600 CPM  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Riehle-Los

C/W .002 CL. HiLok  
 Prot. Head .010 Shim

Specimen No. R623080	Typical Hole Diameter Before CW (Inches)	Typical Final Hole Diameter (Inches)	Cycles to Failure	Origin of Failure and Remarks	LOAD
-112	.3545	.3755	281,720	 Origin at 45° to $Q_L$ No surface fretting	
-113	.3545	.3755	291,700	 Origin at 20° to $Q_L$ No surface fretting	
-114	.3545	.3755	355,200	 Origin at 90° to $Q_L$ No surface fretting	

▷ Some secondary cracks at 45° away from hole on load side.

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 G 3

## GENERAL TEST CONDITIONS

DATE: 4-23-73

### 1. Specimen Description

High Load Transfer: Fig. 10  
 Material: 2024 T 851  
 Material Gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: HI-Lok, Prot. Head

### 3. Fastener Installation:

Fastener Fit: .002" Int.  
 Installation Torque: 225/250 in/lbs



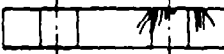
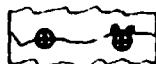
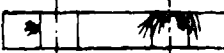
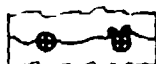
### 2. Hole Preparation

Nominal Hole Size: 3/8"  
 Process: Ream, C/W, Ream  
 CW Process: Sleeve  
 CW Interference: 0.0185"

### 4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 16,800 lbs.  
 Load Ratio: R = 0.1  
 Test Frequency: 600 CPM  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Riehle-Los

C/W Interference Fit HI-Lok  
 Prot. Head .010" Shim

Specimen No. R623080	Typical Hole Diameter Before CW (Inches)	Typical Final Hole Diameter (Inches)	Cycles to Failure	Origin of Failure and Remarks	LOAD
-115	.3545	.3715	924, 180	 ORIGIN AT 0° FROM G. NO SURFACE FRETTING	
-116	.3545	.3715	655, 880	 SOME 90° SHANK FRETTING ORIGIN 0° FROM G. NO SURFACE FRETTING	
-117	.3545	.3715	900, 530	 45° SHANK FRETTING MAIN ORIGIN 0° FROM G. NO SURFACE FRETTING	

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 G 4

## GENERAL TEST CONDITIONS

DATE: 4-26-73

### 1. Specimen Description

High Load Transfer: Fig 10  
 Material: 2024 T 851  
 Material Gauge: 0.250  
 Surface Treatment: Shot Peen  
 Fastener: HI-Lok, Flush Head

### 3. Fastener Installation:

Fastener Fit: Net  
 Installation Torque: 225/250 in/lbs

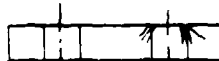



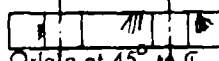
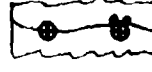
### 2. Hole Preparation

Nominal Hole Size: 3/8"  
 Process: Ream, C/W, Ream, CSK  
 CW Process: Sleeve  
 CW Interference: 0.019"

### 4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 16,800 lbs.  
 Load Ratio: R = 0.1  
 Test Frequency: 600 CPM  
 Test Laboratory: Materials  
 Test Engineer: D. Rees  
 Test Machine: Riehle-Los

C/W Net Fit HI-Lok  
 Flush Head .010" Shim

Specimen No. R623080	Typical Hole Diameter Before CW (Inches)	Typical Final Hole Diameter (Inches)	Cycles to Failure	Origin of Failure and Remarks	LOAD
-118	.3545	.3732	508, 360	 Origin at 0° to $\phi$ No surface fretting	
-119	.3545	.3732	343, 460	 Origin at 45° to $\phi$ No surface fretting	
-120	.3545	.3732	557, 400	 Origin at 45° to $\phi$ No surface fretting	

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 C 5

## GENERAL TEST CONDITIONS

DATE: 4-26-73

### 1. Specimen Description

High Load Transfer: Fig. 10  
Material: 2024 T 851  
Material Gauge: 0.250"  
Surface Treatment: Shot Peen  
Fastener: Hi-Lok (Prot. Head)

### 3. Fastener Installation:

Fastener Fit: Net fit  
Installation Torque: 225/250 in/lbs  
NO SHIM



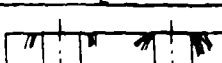

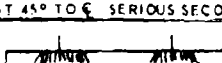
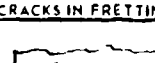
### 2. Hole Preparation

Nominal Hole Size: 3/8"  
Process: Ream, C/W & Ream  
CW Process: Sleeve  
CW Interference: 0.0185

### 4. Fatigue Conditions

Net Stress: 30 ksi  
Test Load: 16,800 lbs.  
Load Ratio: R=0.1  
Test Frequency: 600 CPM  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Riehle-Los

C/W Net Fit HiLok  
Prot. Head - No Shim

Specimen No. R623080	Typical Hole Diameter Before CW (Inches)	Typical Final Hole Diameter (Inches)	Cycles to Failure	Origin of Failure and Remarks	LOAD
-121	.3545	.3735	294, 720	 SURFACE FRETTING ON LOAD SIDE ORIGINS AT 45° TO G	
-123	.3545	.3735	386, 990	 SERIOUS SURFACE FRETTING ON LOAD SIDE ORIGIN AT 45° TO G. SERIOUS SECONDARY CRACKS IN FRETTING	
-123	.3545	.3735	399, 190	 ORIGIN AT 0° TO G SURFACE FRETTING ON LOAD SIDE	

NOTE: Surface fretting only occurs on load side at first row of holes.

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 G 6

## GENERAL TEST CONDITIONS

DATE: 4-27-73

### 1. Specimen Description

High Load Transfer: Fig. 10  
 Material: 2024 T 851  
 Material Gauge: 0.250  
 Surface Treatment: Shot Peen  
 Fastener: Hi-Lok (Prot. Head)

### 3. Fastener Installation:

Fastener Fit: Net  
 Installation Torque: 225/250 in/lbs

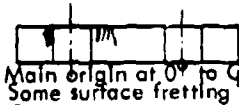
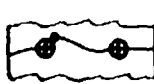
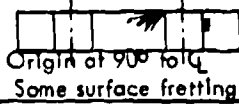
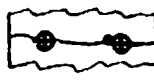
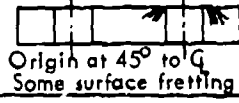
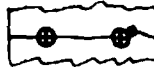
### 2. Hole Preparation

Nominal Hole Size: 3/8"  
 Process: Ream. C/W, Ream  
 CW Process: Sleeve  
 CW Interference: 0.0185"

### 4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 16,800 lbs.  
 Load Ratio: R = 0.1  
 Test Frequency: 600 CPM  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Riehle-Los

C/W Net Fit HiLok  
 Prot. Head No Shim  
 Upset Removed &  
 Primed

Specimen No. R623080	Typical Hole Diameter Before CW (Inches)	Typical Final Hole Diameter (Inches)	Cycles to Failure	Origin of Failure and Remarks	LOAD
-124	.3545	.3735	429,000	 <p>Main origin at 0° to Q<sub>1</sub> Some surface fretting</p>	
-125	.3545	.3735	674,690	 <p>Origin at 90° to Q<sub>1</sub> Some surface fretting</p>	
-126	.3545	.3735	990,370	 <p>Origin at 45° to Q<sub>1</sub> Some surface fretting</p>	

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 G 7

## GENERAL TEST CONDITIONS

DATE: 4-27-73

### 1. Specimen Description

High Load Transfer: Fig. 10  
 Material: 2024 T 851  
 Material Gauge: 0.250  
 Surface Treatment: Shot Peen  
 Fastener: Taper-Lok (Prot. Head)

### 3. Fastener Installation:

Fastener Fit: Net  
 Installation Torque: 225/250 in/lbs.

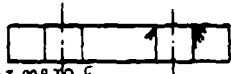
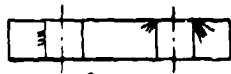
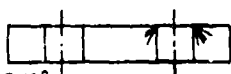
### 2. Hole Preparation

Nominal Hole Size: 3/8"  
 Process: Ream only

### 4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 16,800 lbs.  
 Load Ratio: R = 0.1  
 Test Frequency: 600 CPM  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Riehle-Los

T/L Prot. Head .010 Shim

Specimen No. R623080	Typical Hole Diameter Before CW (Inches)	Typical Head Protrusion (Inches)	Cycles to Failure	Origin of Failure and Remarks	LOAD
-127	-	.230/.250	682,310	ORIGIN AT 90° TO $\epsilon$ NO SURFACE FRETTING	
-128	-	.230/.250	741,500	MAIN ORIGIN AT 45° FRETTING IN FAILED HOLE AT SIDES NO SURFACE FRETTING	
-129	-	.230/.250	369,400	ORIGIN AT 45° FRETTING IN FAILED HOLE AT SIDES NO SURFACE FRETTING	

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 G 8

## GENERAL TEST CONDITIONS

DATE: 4-25-73

### 1. Specimen Description

High Load Transfer: Fig. 10  
 Material: 2024 T 851  
 Material Gauge: 0.250  
 Surface Treatment: Shot Peen  
 Fastener: Taper-Lok, 100° head

### 3. Fastener Installation:

Fastener Fit: \_\_\_\_\_  
 Installation Torque: 225/250 in./lbs.

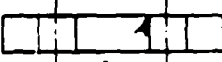

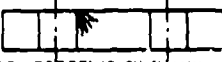
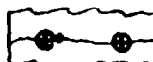
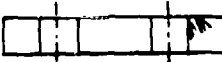

### 2. Hole Preparation

Nominal Hole Size: 3/8"  
 Process: Ream

### 4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 16,800 lbs.  
 Load Ratio: R = 0.1  
 Test Frequency: 600 CPM  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Riehle-Los

T/L Flush Head .010" Shim

Specimen No. R623080	Typical Hole Diameter Before CW (Inches)	Typical Head Protrusion (Inches)	Cycles to Failure	Origin of Failure and Remarks	LOAD
-130	-	.230/.250	1,422,370	 ORIGIN AT 45° TO Q NO SURFACE FRETTING	
-131	-	.230/.250	517,810	 CORKSCREW FRETTING ON SHANK ORIGIN ON 0° TO Q NO SURFACE FRETTING	
-132	-	.230/.250	548,000	 ORIGIN AT 90° TO Q SOME SHANK FRETTING NO SURFACE FRETTING	

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 G 9

## GENERAL TEST CONDITIONS

DATE: 5-3-73

### 1. Specimen Description

High Load Transfer: Fig. 10  
 Material: 2024 T 851  
 Material Gauge: 0.250  
 Surface Treatment: Shot Peen  
 Fastener: Hi-Lok (Prot. Head)

### 3. Fastener Installation:

Fastener Fit: Net  
 Installation Torque: 225/250 In./lbs.

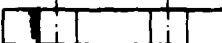

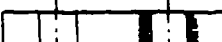



### 2. Hole Preparation

Nominal Hole Size: 3/8"  
 Process: Drill and ream

### 4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 16,800 lbs.  
 Load Ratio: R = 0.1  
 Test Frequency: 600 CPM  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Riehle-Los

Reamed Net Fit HiLok  
 Prot. Head .010" Shim

Specimen No. R623080	Typical Hole Diameter Before CW (Inches)	Typical Final Hole Diameter (Inches)	Cycles to Failure	Origin of Failure and Remarks	LOAD
-133	-	.3735	201,290	 Origin at 90° to Q No surface fretting	
-134	-	.3735	151,220	 Origin at 90° to Q No surface fretting	
-135	-	.3735	122,060	 Origin at 90° to Q No surface fretting	

# PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 G 10

## GENERAL TEST CONDITIONS

DATE: 5-7-73

### 1. Specimen Description

High Load Transfer: Fig 10  
 Material: 2024 T 851  
 Material Gauge: 0.250  
 Surface Treatment: Shot Peen  
 Fastener: Hi-Lok (Prot. Head)

### 3. Fastener Installation:

Fastener Fit: Net  
 Installation Torque: 225/250 in/lbs.  
.060 sand blasted Micarta

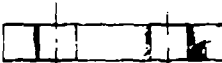

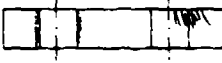
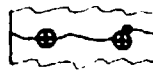
### 2. Hole Preparation

Nominal Hole Size: 3/8"  
 Process: C/W, ream  
 C/W Process: Sleeve  
 C/W Interference: 0.0185"

### 4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 16,800 lbs.  
 Load Ratio: R = 0.1  
 Test Frequency: 600 CPM  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Riehle-Los

C/W Net Fit HiLok  
 Prot. Head .060" Shim

Specimen No. R623080	Typical Hole Diameter Before CW (Inches)	Typical Final Hole Diameter (Inches)	Cycles to Failure	Origin of Failure and Remarks	LOAD
-136	.3545	.3735	365,020	 No surface fretting	
-137	.3545	.3735	867,530	 No surface fretting	

[illegible]


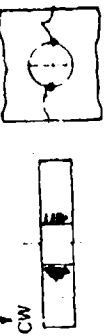
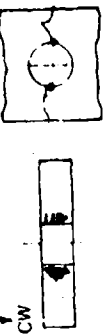
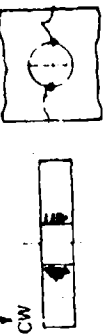


2. The second part of the paper discusses the impact of the 1997-1998 Asian financial crisis on the performance of the Asian economies. The paper shows that the crisis had a significant impact on the performance of the Asian economies, particularly in the area of economic growth and employment. The paper also discusses the impact of the crisis on the financial markets of the Asian economies.

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
90 split, open,  
70 ksi

TEST 4A1 SPECIMEN 623080 DATE 10/3/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference	0.019	Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti 6Al-4V (annealed)	Sleeve type	Split	Process	Ream, C/W, ream	Max test load (kip)	20.8
Width (in.)	1.50	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation	89			Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in/in.)	0.045	Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.353	Fit		Test machine	36 kip Vibraphore
		Lubrication	Fel Pro 300	Torque (in. lb)			

Specimen dash no.	Hole no.	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
1	1	0.3550	0.3540	0.3745	30	25	30	0.0180	0.0090			179,000	
2	2	0.3550	0.3640	0.3745	-	-	-	0.0180	0.0090				
3	3												
4	4												
2	1	0.3550	0.3640	0.3745	35	25	30	0.0180	0.0090			87,000	
	2	0.3550	0.3640	0.3745	-	-	-	0.0180	0.0090				
3	3												
4	4												
3	1	0.3550	0.3640	0.3745	30	25	35	0.0180	0.0090			79,000	
	2	0.3550	0.3640	0.3745	-	-	-	0.0180	0.0090				
3	3												
4	4												

Ti-6Al-4V,  
C/W, drilled hole,  
70 ksi

TEST	SPECIMEN	DATE
4A2 (T)	623080	10/16/73

## SPECIMEN DESCRIPTION

Configuration	Fig. 2
Material	Ti-6Al-4V (annealed)
Width (in.)	1.50
Hole spacing (in.)	1.50
Edge margin (in.)	0.75
Material gauge (in.)	0.250
Surface treatment	Shot peen

## COLDWORK PROCESS

Interference (in.)	0.019
Sleeve type	Split
Sleeve thickness (in.)	0.010
Sleeve orientation	0°
Mandrel material	AISI 9260 steel
Mandrel taper (in./in.)	0.045
Mandrel max. diameter (in.)	0.353
Lubrication	Fel Pro 300

## HOLE PREPARATION

Nominal hole size (in) 0.375

Process Drill (good), C/W, ream

**STENER INSTALLATION**

Type \_\_\_\_\_

Fit \_\_\_\_\_

Torque (in. lb) \_\_\_\_\_

## FATIGUE CONDITIONS

Max net stress (ksi)	70
Max test load (kip)	20.5
Load ratio (R)	0.1
Test frequency	4000 cpm
Test laboratory	Materials
Test engineer	D. Reese
Test machine	36 kip Vibraphore

[illegible]

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-6V,  
C/W, abusively drilled hole,  
70 ksi

TEST 4A3 (T) SPECIMEN 623080 DATE 10/16/73

## SPECIMEN DESCRIPTION

Fig. 2  
Configuration Ti-6Al-4V (annealed)  
Material 1.50  
Width (in.) 1.50  
Hole spacing (in.) 0.75  
Edge margin (in.) 0.250  
Material gauge (in.) Shot peen  
Surface treatment

## COLDWORK PROCESS

Interference (in.) 0.019  
Sleeve type Split  
Sleeve thickness (in.) 0.010  
Sleeve orientation 0°  
Mandrel material AISI 9260 steel  
Mandrel taper (in./in.) 0.045  
Mandrel max diameter (in.) 0.353  
Lubrication Fel Pro 300

## HOLE PREPARATION

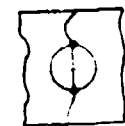
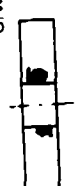
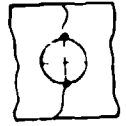
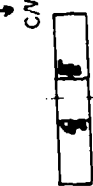
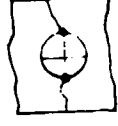

Nominal hole size (in.) 0.375  
Process Drill (abusively) C/W, ream

## FASTENER INSTALLATION

Type  
Fit  
Torque (in. lb)

## FATIGUE CONDITIONS

Max net stress (ksi) 70  
Max test load (kip) 20.5  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 36-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHRI)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
7	1	0.3565	0.3655	0.3750	65	40	30	0.0165	0.0090			47,000	
	2	0.3570	0.3660	0.3750				0.0160	0.0090				
	3												
	4												
8	1	0.3570	0.3655	0.3750	65	45	30	0.0160	0.0085			43,000	
	2	0.3570	0.3655	0.3750	70			0.0160	0.0085				
	3												
	4												
9	1	0.3580	0.3660	0.3750	75	45	30	0.0150	0.0080			54,000	
	2	0.3590	0.3660	0.3750				0.0140	0.0070				
	3												
	4												

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
C/W open,  
no postream,  
70 ksi

TEST 4A4 SPECIMEN 623080 DATE 10/3/73

## SPECIMEN DESCRIPTION

Configuration Fig. 2  
Material Ti 6Al-4V (annealed)  
Width (in.) 1.50  
Hole spacing (in.) 1.50  
Edge margin (in.) 0.75  
Material gauge (in.) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS

Interference (in.) 0.019  
Sleeve type Split  
Sleeve thickness (in.) 0.010  
Sleeve orientation 0°  
Mandrel material AISI 9260 steel  
Mandrel taper (in/in) 0.045  
Mandrel max diameter (in) 0.353

## HOLE PREPARATION

Nominal hole size (in) 0.375  
Process Ream C/W







## FATIGUE CONDITIONS

Max net stress (ksi) 70  
Max test load (kip) 20.5  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 36 kip Vibraphore

Torque (in. lb)

Fel Pro 300

Lubrication

Specimen dash no	Hole no	Hole diameter (in)			Hole finish (RHRI)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
10	1	0.3540	0.3630	0.3745	35	20	35	0.0190	0.0090			79,000	
	2	0.3540	0.3630	0.3745	-	-	-	0.0190	0.0090				
	3												
	4												
11	1	0.3540	0.3670	0.3745	35	20	35	0.0190	0.0090			88,000	
	2	0.3540	0.3630	0.3745	-	-	-	0.0190	0.0090				
	3												
	4												
12	1	0.3540	0.3630	0.3745	35	20	30	0.0190	0.0090			82,000	
	2	0.3540	0.3630	0.3745	-	-	-	0.0190	0.0090				
	3												
	4												

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
C/W open,  
scored,  
70 ksi

TEST: 4A5 SPECIMEN 623080 DATE 10/3/73

SPECIMEN DESCRIPTION		COLDWORK PROCESSES		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference (in.)	0.019	Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti-6Al-4V (annealed)	Sleeve type	Split	Process	Ream, C/W, ream score, one hole	Max test load (kip)	20.4
Width	1.50	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation	0°			Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material type (in.)	0.250	Mandrel taper (in./in.)	0.045	Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.353	Fit		Test machine	36 kip vibraphore
		Lubrication	Fel Pro 300	Torque (in. lb)			

Specimen dash no.	Hole no.	Hole diameter (in.)				Hole finish (RHRI)				Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit				
13	1	0.3540	0.3630	0.3745	35		20	0.0190	0.0090					85,000	C/W
	2	0.3540	0.3630	0.3745				0.0190	0.0090						Failed in scored hole
	3														
	4														
14	1	0.3540	0.3635	0.3745	35		20	0.0190	0.0095					72,000	C/W
	2	0.3540	0.3635	0.3745				0.0190	0.0095						Failed in scored hole
	3														
	4														
15	1	0.3540	0.3630	0.3745	35		20	0.0190	0.0090					76,000	C/W
	2	0.3540	0.3630	0.3745				0.0190	0.0090						Failed in scored hole
	3														
	4														Failed in scored hole

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
open, 1/64 postream,  
70 ksi

TEST 4A6 SPECIMEN 623080 DATE 10/12/73

## SPECIMEN DESCRIPTION

Fig. 2

Configuration Ti-6Al-4V (annealed)  
Material  
Width (in.) 1.50  
Hole spacing (in.) 1.50  
Edge margin (in.) 0.75  
Material gauge (in.) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS

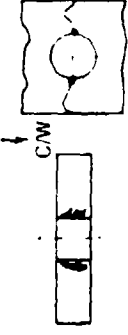
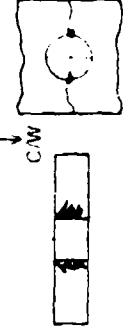
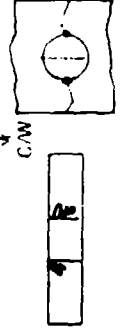
Interference (in.) 0.019  
Sleeve type Split  
Sleeve thickness (in.) 0.010  
Sleeve orientation 0°  
Mandrel material AISI 9260 steel  
Mandrel taper (in/in) 0.045  
Mandrel max diameter (in) 0.353  
Lubrication Fel Pro 300

## HOLE PREPARATION

Nominal hole size (in) 0.375  
Process Ream, C/W, ream,  
1/64 oversize

## FATIGUE CONDITIONS

Max net stress (ksi) 70  
Max test load (kip) 20.2  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 36-kip Vibraphore

Specimen tag no.	Hole diameter (in.)				Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
	Before coldwork	After coldwork	After ream	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
.16	1	0.3540	0.3635	0.3900	35	20	40	0.019	0.0095			61,000	
	2	0.3540	0.3635	0.3900				0.019	0.0095				
	3												
	4												
.17	1	0.3540	0.3630	0.3900	35	20	45	0.019	0.0090			64,000	
	2	0.3540	0.3630	0.3900				0.019	0.0090				
	3												
	4												
.18	1	0.3540	0.3635	0.3900	35	15	45	0.019	0.0095			64,000	
	2	0.3540	0.3635	0.3900				0.019	0.0095				
	3												
	4												





# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V  
square wire sleeve,  
70 ksi

TEST 4A9 SPECIMEN 623080 DATE 10/12/73

## SPECIMEN DESCRIPTION

Fig. 2  
Configuration  
Material Ti-6Al-4V (annealed)  
Width (in.) 1.50  
Hole spacing (in.) 1.50  
Edge margin (in.) 0.75  
Material grade (in.) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS





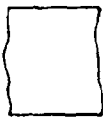

Interference (in.) 0.019  
Sleeve type Square wire  
Sleeve thickness (in.) 0.018  
Sleeve orientation -  
Mandrel material AISI 9260 steel  
Mandrel taper (in/in) 0.045  
Mandrel max diameter (in.) 0.353  
Lubrication Fel-Pro 300

## HOLE PREPARATION

Nominal hole size (in.) 0.375  
Process Ream, C/W, ream

## FATIGUE CONDITIONS

Max net stress (ksi) 70  
Max test load (lb) Not tested  
Load ratio (R) 0.1  
Test frequency Not tested  
Test laboratory Not tested  
Test engineer Not tested  
Test machine Not tested

Specimen dash no	Hole no	Hole diameter (in.)				Hole finish (RHRI)				Coldwork expansion (in.)			Fastener size (in.)			Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit						
25	1	0.3715														 	
	2	0.3715															
	3																
	4																
26	1	0.3715														 	
	2	0.3715															
	3																
	4																
27	1	0.3715														 	
	2	0.3715															
	3																
	4																

Square wire sleeve crimped in coldworking specimen

Not completed

Not completed  
Square wire sleeve crimped in coldworking specimen

Ti-6Al-4V,  
0.060-in. gage mtl  
70 ksi

TEST 4B1 SPECIMEN 623080 DATE 10/3/73

## SPECIMEN DESCRIPTION

Fig. 2

Ti-6Al-4V (annealed)

1.50

150

0.75

0000

100

**Figure 1**

## COLLAPSE PROCESS

Interference (in.)

2

144

## HOLE PREPARATION

Nominal hole size (in)

Process

10-10-68

## FASTENER INSTALLATION

**T. 100**

...

## FATIGUE CONDITIONS

Max net stress (ksi)

(b)(7)(F) Privacy - 2008-2009

1000-0000 (P)

## References

1  
2  
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5  
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[illegible]

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V  
one hole, C/W,  
70 ksi

TEST 4C1 SPECIMEN 623080 DATE 10/4/73

## SPECIMEN DESCRIPTION

Fig 2  
Configuration Ti-6Al-4V (annealed)  
Material 1.50  
Width (in.) 1.50  
Hole spacing (in.) 0.75  
Edge margin (in.) 0.250  
Material grade (in.) Shot peen  
Surface treatment

## COLDWORK PROCESS

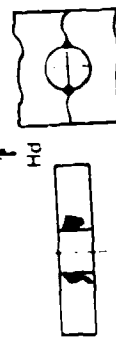
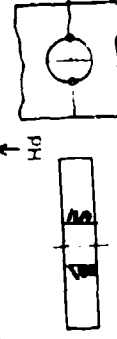
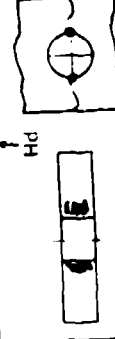

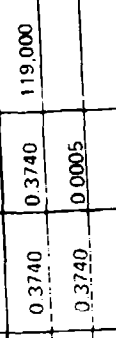
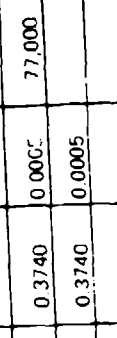
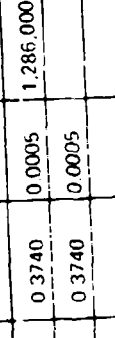

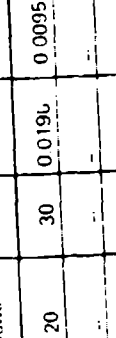
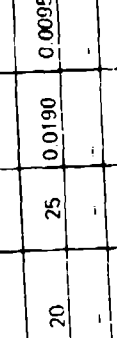
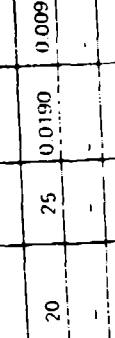

Interference (in.) 0.019  
Sleeve type Split  
Sleeve thickness (in.) 0.010  
Sleeve orientation 0°  
Mandrel material AISI 9260 steel  
Mandrel taper (in./in.) 0.045  
Mandrel max diameter (in.) 0.353  
Lubrication Fat Pro 300

## HOLE PREPARATION

Nominal hole size (in.) 0.375  
Process Ream one hole,  
ream, C/W, ream one hole  
FASTENER INSTALLATION  
Type Hi-Lok, pilot hd  
Fit Net to 0.0005 clearance  
Torque (in.-lb) 240-250

## FATIGUE CONDITIONS

Max net stress (ksi) 70  
Max test load (kip) 20.5  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 36 Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)				Hole finish (RHRI)				Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit				
31	1	0.3540	0.3635	0.3745	35	20	30	0.0190	0.0095	0.3740	0.3740	119,000		Failed in reamed hole	
	2	-	-	0.3745	-	-	-	-	-	0.3740	0.0005	-		Failed in reamed hole	
	3	-	-	-	-	-	-	-	-	-	-	-		Failed in reamed hole	
	4	-	-	-	-	-	-	-	-	-	-	-		Failed in reamed hole	
32	1	0.3540	0.3635	0.3745	35	20	25	0.0190	0.0095	0.3740	0.0005	77,000		Failed in reamed hole	
	2	-	-	0.3745	-	-	-	-	-	0.3740	0.0005	-		Failed in reamed hole	
	3	-	-	-	-	-	-	-	-	-	-	-		Failed in reamed hole	
	4	-	-	-	-	-	-	-	-	-	-	-		Failed in reamed hole	
33	1	0.3540	0.3635	0.3745	35	20	25	0.0190	0.0095	0.3740	0.0005	1,286,000		Failed in reamed hole	
	2	-	-	0.3745	-	-	-	-	-	0.3740	0.0005	-		Failed in reamed hole	
	3	-	-	-	-	-	-	-	-	-	-	-		Failed in reamed hole	
	4	-	-	-	-	-	-	-	-	-	-	-		Failed in reamed hole	

Ti-6Al-4V,  
C/W, 0.002 clearance Hi-Lok,  
70 ksi

TEST 4C2 SPECIMEN 623080 DATE 10/15/73

## SPECIMEN DESCRIPTION

**Fig. 2**

**Configuration**

**Material**

**Ti-6Al-4V (annealed)**

1.50

Hole spacing (in.)

1.50

0.075

0.250

Surface treatment

## COLDWORK PROCESS

Interference (in.)

Signe Lyde

Classroom: 100

### Sleep orientation

**Mandarin** **mandarin**

1000

Mantel max diameter

## HOLE PREPARATION

Nominal hole size (in)

## Process

STENED INSTANT

 $\varepsilon_i$  (in.)

## FASTENER INSTALLATION

—

 $\varepsilon_1$  (in.)

Torque (in.·lb)

## FATIGUE CONDITIONS

Max net stress (ksi)	70
----------------------	----

Max rest load (kin) 20.1

0.1

Test frequency

## Materials

D. Reese

Test machine

[illegible]

# PHASE II—TASK 4— APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V  
C/W, 0.002 interference, Hi-Lok  
70 ksi

TEST 4C3 SPECIMEN 623080 DATE 10/15/73

## SPECIMEN DESCRIPTION

Fig. 2

Configuration	Ti-6Al-4V (annealed)
Material	
Width (in.)	1.50
Hole spacing (in.)	1.50
Edge margin (in.)	0.75
Material gauge (in.)	0.250
Surface treatment	Shot peen

## COLDWORK PROCESS

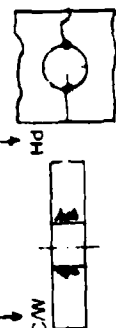
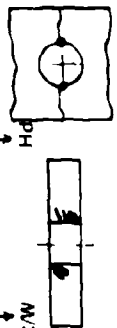
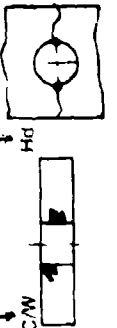
Interference (in.)	0.019
Sleeve type	Split
Sleeve thickness (in.)	0.010
Sleeve orientation	0°
Mandrel material	AISI 9260 steel
Mandrel taper (in./in.)	0.045
Mandrel max diameter (in.)	0.353
Lubrication	Fel-Pro 300

## HOLE PREPARATION

Nominal hole size (in.)	0.375
Process	Ream, C/W, ream
FASTENER INSTALLATION	
Type	Hi-Lok prot hd
Fit (in.)	0.002 interference
Torque (in. lb)	240-250

## FATIGUE CONDITIONS

Max net stress (ksi)	70
Max test load (kip)	20.2
Load ratio (R)	0.1
Test frequency	4000 cpm
Test laboratory	Materials
Test engineer	D. Reese
Test machine	36 Vitraphore

Specimen dash no.	Hole no.	Hole diameter (in.)			Hole finish (IRHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
37	1	0.3540	0.3620	0.3715	35	15	30	0.0190	0.0110	0.3735	0.002	4,421,000	
	2	0.3540	0.3630	0.3715	-	-	-	0.0190	0.0100	0.3735	0.002		
	3												
	4												
38	1	0.3540	0.3630	0.3715	35	15	30	0.0190	0.0100	0.3735	0.002	6,836,000	
	2	0.3540	0.3630	0.3715	-	-	-	0.0190	0.0100		0.002		
	3												
	4												
39	1	0.3540	0.3620	0.3715	35	15	40	0.0190	0.0100	0.3735	0.002	824,000	
	2	0.3540	0.3620	0.3715	-	-	-	0.0190	0.0110		0.002		
	3												
	4												

Ti 6Al-4V  
100° csk after C/W.  
70 ksi

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST 4C4 SPECIMEN 623080 DATE 10/17/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference (in.)	0.019	Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti 6Al-4V (annealed)	Sleeve type	split	Process	C/W, ream, csk	Max test load (kip)	20.5
Width (in.)	1.50	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation	0°			Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)	0.045	Type	Hi-Lok 100-hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.353	Fu (in.)	Net to 0.0005 clearance	Test machine	36-kip Vibraphore
		Lubrication	Fel Pro 300	Torque (in. lb)	240-250		

Specimen dash no.	Hole no.	Hole diameter (in.)				Hole finish (Ra/Rz)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	After finish	Before coldwork	After ream	Actual	Retained	Diameter	Fu		
40	1	0.3545	0.3630	0.3750	20	35	30	0.0185	0.0085	0.3745	0.0005	217,000	↑ C/W Hd
	2	0.3545	0.3630	0.3750	-	-	-	0.0185	0.0085	0.3745	0.0005		
	3												
	4												
41	1	0.3545	0.3630	0.3750	20	35	30	0.0185	0.0085	0.3745	0.0005	212,000	↑ C/W Hd
	2	0.3545	0.3630	0.3750	-	-	-	0.0185	0.0085	0.3745	0.0005		
	3												
	4												
42	1	0.3545	0.3620	0.3750	20	35	30	0.0185	0.0075	0.3745	0.0005	483,000	↑ C/W Hd
	2	0.3545	0.3620	0.3750	-	-	-	0.0185	0.0075	0.3745	0.0005		
	3												
	4												

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
100° csk before C/W,  
70 ksi

TEST 4C5 SPECIMEN 623080 DATE 10/17/73

## SPECIMEN DESCRIPTION

Fig. 2

Configuration \_\_\_\_\_  
Material Ti-6Al-4V (annealed)  
Width (in.) 1.50  
Hole spacing (in.) 1.50  
Edge margin (in.) 0.75  
Material gauge (in.) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS

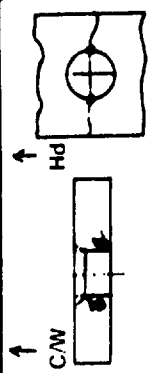
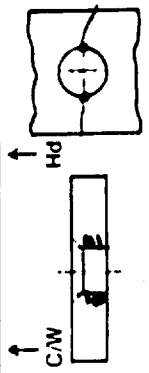
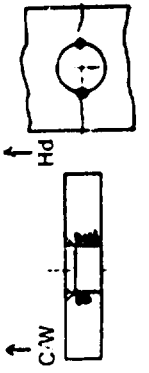
Interference (in.) 0.019  
Sieve type Split  
Sieve thickness (in.) 0.010  
Sieve orientation 0°  
Mandrel material AISI 9260 steel  
Mandrel taper (in./in.) 0.045  
Mandrel max diameter (in.) 0.353  
Lubrication Fel Pro 300

## HOLE PREPARATION

Nominal hole size (in.) 0.375  
Process Csk, C/W, ream  
Type Hi-Lok flush hd  
Fit (in.) Net to 0.0005 clearance  
Torque (in. lb) 240-250

## FATIGUE CONDITIONS

Max net stress (ksi) 70  
Max test load (kip) 20.1  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 36 kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
43	1	0.3550	0.3635	0.3745	30	10	20	0.0180	0.0085	0.3740	0.0005	760,000	
	2	0.3545	0.3635	0.3745	-	-	-	0.0185	0.0090	0.3740	0.0005		
	3												
	4												
44	1	0.3545	0.3635	0.3745	30	10	20	0.0185	0.0090	0.3740	0.0005	757,000	
	2	0.3545	0.3635	0.3745	-	-	-	0.0185	0.0090	0.3740	0.0005		
	3												
	4												
45	1	0.3545	0.3635	0.3745	30	10	20	0.0185	0.0090	0.3740	0.0005	1,064,000	
	2	0.3545	0.3625	0.3745	-	-	-	0.0185	0.0090	0.3740	0.0005		
	3												
	4												

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti 6Al-4V,  
70° csk after C/W,  
70 ksi

TEST 4C6 SPECIMEN 623080 DATE 10/17/73

## SPECIMEN DESCRIPTION

Configuration Fig. 2  
Material Ti 6Al 4V (annealed)  
Width (in.) 1.50  
Hole spacing (in.) 1.50  
Edge margin (in.) 0.75  
Material size (in.) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS

Interference (in.) 0.019  
Sleeve type Split  
Sleeve thickness (in.) 0.010  
Sleeve or entation 0°  
Mandrel material AISI 9260 steel  
Mandrel taper (in/in) 0.045  
Mandrel max diameter (in) 0.353  
Lubrication Fel Pro 300

## HOLE PREPARATION

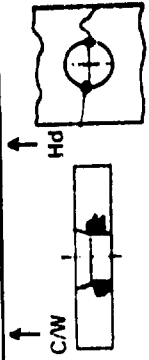
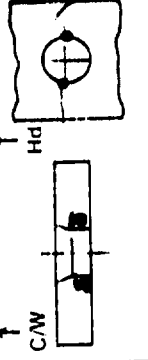
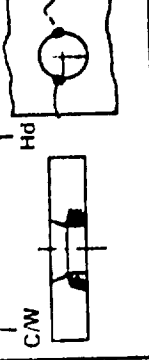
Nominal hole size (in.) 0.375  
Process C/W, ream, csk

## FATIGUE CONDITIONS

Max net stress (ksi) 70  
Max test load (kip) 20.5  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 35-kip Vibraphore

## FASTENER INSTALLATION

Type Boeing radius lead-in bolt, 70° hd  
Fit Net to 0.001 interference  
Torque (in. lb) 240-250

Specimen Tag No.	Hole No.	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
46	1	0.3545	0.3620	0.3790	35	20	30	0.0185	0.0075	0.3800	0.001	555,000	
	2	0.3545	0.3620	0.3790	-	-	-	0.0185	0.0075	0.3800	0.001		
	3												
	4												
47	1	0.3545	0.3625	0.3790	35	20	30	0.0185	0.0080	0.3800	0.001	570,000	
	2	0.3545	0.3620	0.3790	-	-	-	0.0185	0.0080	0.3800	0.001		
	3												
	4												
48	1	0.3545	0.3620	0.3790	35	20	30	0.0185	0.0075	0.3800	0.001	435,000	
	2	0.3545	0.3620	0.3790	-	-	-	0.0185	0.0075	0.3800	0.001		
	3												
	4												

Ti-6Al-4V,  
prefatigue,  
C/W, net fit Hi-Lok,  
70 ksi

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST 4C7(T) SPECIMEN 623080 DATE 11/16/73

FATIGUE CONDITIONS

Max net stress (ksi) 70

Max test load (kip) 20

Load ratio (R) 0.1

Test frequency 4000 cpm

Test laboratory Materials

Test engineer D. Reese

Test machine 36-kip Vibraphore

HOLE PREPARATION

Nominal hole size (in.) 0.375

Process Ream undersize,  
install fastener,  
fatigue 80 000 cycles  
ream, C/W, ream

SPECIMEN DESCRIPTION

Fig. 2

Configuration Ti-6Al-4V (annealed)

Material 1.50

Width (in.) 1.50

Hole spacing (in.) 0.75

Edge margin (in.) 0.250

Material grade (in.) Shot peen

Surface treatment

COLDWORK PROCESS

Pre-finish (in.) 0.019

Process Split

0.010

0°

AISI 9260 steel

FASTENER INSTALLATION

Type Hi-Lok, prot hd

Fit (in.) Net to 0.0005 clearance

240 250

Torque (in lb)

Fel Pro 300

Specimen no.	Hole no.	Hole diameter (in.)		Hole finish (RH/R)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
49	1										
	2										
	3										
	4										
50	1	0.3540	0.3635	0.3735	30	15	25	0.0190	0.0095	Net	709,000
	2	0.3540	0.3635	0.3735	-	-	-	0.0190	0.0095	Net	
	3										
	4										
51	1	0.3540	0.3635	0.3735	30	15	25	0.0190	0.0095	Net	431,000
	2	0.3540	0.3635	0.3735				0.0190	0.0095	Net	
	3										
	4										

of joint in initial cycling

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
precracked,  
C/W, net-fit Hi-Lok,  
70 ksi

TEST 4C8 (T) SPECIMEN 623080 DATE 11/16/73

## SPECIMEN DESCRIPTION

Fig. 2  
Configuration Ti-6Al-4V (annealed)  
Material  
Width (in.) 1.50  
Hole spacing (in.) 1.50  
Edge margin (in.) 0.75  
Material gauge (in.) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS

Interference (in.) 0.019  
Sieve type Split  
Sieve thickness (in.) 0.010  
Sieve orientation 0°  
Mandrel material AISI 9260 steel  
Mandrel taper (in./in.) 0.045  
Mandrel max diameter (in.) 0.353  
Lubrication F-1 Pro 300

## HOLE PREPARATION

Nominal hole size (in.) 0.375  
Process Ream undersize,  
notch, fatigue rack,  
ream, C/W, ream  
FASTENER INSTALLATION  
Type Hi-Lok prot hd  
Fit (in.) Net to 0.0005 clearance  
Torque (in. lb) 240-250

## FATIGUE CONDITIONS

Max net stress (ksi) 70  
Max test load (kip) 20  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 36-kip Vibraphore

Specimen dash no	Hole diameter (in.)			Hole length (RHRI)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
	Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
52	1	0.3540	0.3635	0.3735	30	15	0.0190	0.0095	0.3735	Net	312,000	↑ C/W Failed at hole no. 1; 0.020-in crack remaining after ream
	2	0.3540	0.3635	0.3735	-	-	0.0190	0.0095	0.3735	Net		↑ C/W Failed at hole no. 1; 0.030-in crack remaining after ream
	3											↑ C/W Failed at hole no. 1; 0.030-in crack remaining after ream
	4											↑ C/W Failed at hole no. 2; 0.010-in crack remaining after ream
53	1	0.3540	0.3635	0.3735	30	15	0.0190	0.0095	0.3735	Net	92,000	↑ C/W Failed at hole no. 1; 0.030-in crack remaining after ream
	2	0.3540	0.3635	0.3735	-	-	0.0190	0.0095	0.3735	Net		↑ C/W Failed at hole no. 1; 0.030-in crack remaining after ream
	3											↑ C/W Failed at hole no. 2; 0.010-in crack remaining after ream
	4											↑ C/W Failed at hole no. 2; 0.010-in crack remaining after ream
54	1	0.3540	0.3635	0.3735	30	15	0.0190	0.0095	0.3735	Net	782,000	↑ C/W Failed at hole no. 1; 0.030-in crack remaining after ream
	2	0.3540	0.3635	0.3735	-	-	0.0190	0.0095	0.3735	Net		↑ C/W Failed at hole no. 1; 0.030-in crack remaining after ream
	3											↑ C/W Failed at hole no. 2; 0.010-in crack remaining after ream
	4											↑ C/W Failed at hole no. 2; 0.010-in crack remaining after ream




Fig. 1 Hole crack

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti 6Al4V  
1 1/2 D edge margin,  
open, C/W,  
70 ksi

TEST 4D1(T) SPECIMEN 623080 DATE 10/22/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig 7A	Interference (in.)	0.019	Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti 6Al4V (annealed)	Sleeve type	Split	Process	Ream, C/W, ream	Max test load (kip)	41.6
Width (in.)	3.125	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	3.50 x 2	Sleeve Orientation	0°			Test frequency	4000 cpm
E for margin (in.)	0.562	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Materials
Fastener size (in.)	0.250	Mandrel taper (in/in)	0.045	Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.3530	Fit		Test machine	100 kip Vibraphore
		Location	Fel Pro 300	Torque (in. lb)			

Specimen designation	Hole diameter (in.)				Hole finish (HHR)			Coldwork extension (in.)		Fastener size (in.)		Cycles to failure	Origin of failure (a) and remarks
	Before coldwork	After coldwork	After ream	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Pil		
85	1	0.3550	0.3645	0.3745	70	15	40	0.0180	0.0095			46,000	 C/W
	2	0.3550	0.3645	0.3745	-	-	-	0.0180	0.0095				
	3	0.3550	0.3645	0.3745	25	15	35	0.0180	0.0095				
	4	0.3550	0.3645	0.3745	-	-	-	0.0180	0.0095				
86	1	0.3550	0.3645	0.3745	30	15	40	0.0180	0.0095			90,000	 C/W
	2	0.3550	0.3645	0.3745	-	-	-	0.0180	0.0095				
	3	0.3550	0.3645	0.3745	25	15	35	0.0180	0.0095				
	4	0.3550	0.3645	0.3745	-	-	-	0.0180	0.0095				
87	1	0.3550	0.3645	0.3745	35	15	35	0.0180	0.0095			68,000	 C/W
	2	0.3550	0.3645	0.3745	-	-	-	0.0180	0.0095				
	3	0.3550	0.3645	0.3745	30	15	30	0.0180	0.0095				
	4	0.3550	0.3645	0.3745	-	-	-	0.0180	0.0095				

See drawing for hole location and fastener

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
2 D edge margin,  
open, C/W,  
70 ksi

TEST 402 (T) SPECIMEN 623080 DATE 10/19/73

## SPECIMEN DESCRIPTION

Fig. 7B  
Configuration  
Material Ti-6Al-4V (annealed)  
Width (in.) 3.50  
Hole spacing (in.) 3.50 x 2.00  
Edge margin (in.) 0.750  
Material grade (in.) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS


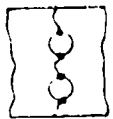

Interference (in.) 0.019  
Sleeve type Split  
Sleeve thickness (in.) 0.010  
Sleeve orientation 0°  
Mandrel material AISI 9260 steel  
Mandrel taper (in/in) 0.045  
Mandrel max diameter (in) 0.353  
Lubrication Fel Pro 300

## HOLE PREPARATION

Normal hole size (in) 0.375  
Process Ream, C/W, ream

## FATIGUE CONDITIONS

Max net stress (ksi) 70  
Max test load (kip) 41.5  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 100 kip Vitraphore

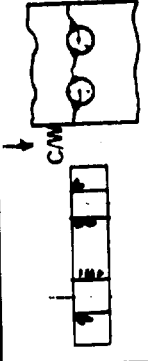
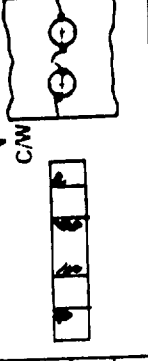
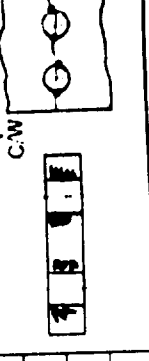
Specimen ID	Hole no.	Hole diameter (in.)				Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After coldwork	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
89	1	0.3550	0.3645	0.3745	0.3745	35	15	3C	0.0180	0.0085			49,000	
	2	0.3550	0.3645	0.3745	0.3745	-	-	-	0.0180	0.0085				
	3	0.3550	0.3645	0.3745	0.3745	30	15	3S	0.0180	0.0085				
	4	0.3550	0.3645	0.3745	0.3745	-	-	-	0.0180	0.0085				
90	1	0.3550	0.3640	0.3745	0.3745	30	15	2S	0.0180	0.0090			56,000	
	2	0.3550	0.3640	0.3745	0.3745	-	-	-	0.0180	0.0090				
	3	0.3550	0.3640	0.3745	0.3745	35	15	3C	0.0180	0.0090				
	4	0.3550	0.3640	0.3745	0.3745	-	-	-	0.0185	0.0090				
91	1	0.3545	0.3640	0.3745	0.3745	30	12	2S	0.0185	0.0095			52,000	
	2	0.3545	0.3640	0.3745	0.3745	-	-	-	0.0185	0.0095				
	3	0.3545	0.3640	0.3745	0.3745	25	10	3C	0.0185	0.0095				
	4	0.3545	0.3640	0.3745	0.3745	-	-	-	0.0185	0.0095				

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
2 1/2-D edge margin,  
open, C/W  
70 ksi

TEST 4D3 (T) SPECIMEN 623080 DATE 10/22/73

<b>SPECIMEN DESCRIPTION</b>		<b>COLDWORK PROCESS</b>		<b>HOLE PREPARATION</b>		<b>FATIGUE CONDITIONS</b>	
Configuration	Fig. 7C	Interference (in.)	0.019	Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti-6Al-4V (annealed)	Sleeve type	Split	Process	Ream, C/W, ream	Max test load (kip)	41.5
Width (in.)	3.875	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	3.50 x 2.00	Sleeve orientation	0°			Test frequency	4000 cpm
Edge margin (in.)	0.937	Mandrel material	AISI 9260 steel	<b>FASTENER INSTALLATION</b>			
Material gage (in.)	0.250	Mandrel taper (in./in.)	0.045	Type		Test laboratory	Materials
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.353	Fit		Test engineer	D. Reese
		Lubrication	Fel Pro 300	Torque (in.-lb.)		Test machine	100-kip Vibraphore


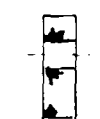

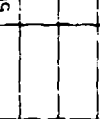





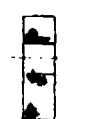


Specimen dash no.	Hole no.	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
93	1	0.3550	0.3645	0.3745	30	15	40	0.0180	0.0095			67,000	
	2	0.3550	0.3645	0.3745	-	-	-	0.0180	0.0095				
	3	0.3550	0.3640	0.3745	35	15	35	0.0180	0.0090				
	4	0.3550	0.3640	0.3745	-	-	-	0.0180	0.0090				
94	1	0.3550	0.3645	0.3745	30	15	40	0.0180	0.0095			63,000	
	2	0.3550	0.3640	0.3745	-	-	-	0.0180	0.0090				
	3	0.3550	0.3645	0.3745	25	10	30	0.0180	0.0095				
	4	0.3550	0.3640	0.3745	-	-	-	0.0180	0.0090				
95	1	0.3550	0.3640	0.3745	30	15	40	0.0180	0.0090			62,000	
	2	0.3550	0.3645	0.3745	-	-	-	0.0180	0.0090				
	3	0.3550	0.3645	0.3745	30	15	40	0.0180	0.0095				
	4	0.3550	0.3640	0.3745	-	-	-	0.0180	0.0090				

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
2 1/2 D edge margin,  
open, C/W,  
70 ksi

TEST 4D4(T) SPECIMEN 623080 DATE 10/23/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 7D	Interference (in.)	0.019	Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti-6Al-4V (annealed)	Sleeve type	Split	Process	Ream, C/W, ream	Max test load (kip)	41.5
Width (in.)	2.995	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	a 1.125 x 1.50	Sleeve orientation	AISI 9260 steel			Test frequency	4000 cpm
Edge margin (in.)	0.4375	Mandrel material	0.045	FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)	0.045	Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.353	Fit		Test machine	100 kip Vibraphore
		Lubrication	Fel Pro 300	Torque (in. lb)			

Specimen tag no.	Hole diameter (in.)				Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
	Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
97	1	0.3545	0.3640	0.3745	40	20	0.0185	0.0095			50,000	
	2	0.3545	0.3640	0.3745	-	-	0.0185	0.0095				
	3	0.3545	0.3640	0.3745	35	15	0.0185	0.0095				
	4	0.3545	0.3640	0.3745	-	-	0.0185	0.0095				
98	1	0.3545	0.3640	0.3750	30	15	0.0185	0.0095			81,000	
	2	0.3545	0.3640	0.3750	-	-	0.0185	0.0095				
	3	0.3545	0.3640	0.3750	35	15	0.0185	0.0095				
	4	0.3545	0.3640	0.3750	-	-	0.0185	0.0095				
100	1	0.3545	0.3640	0.3750	35	15	0.0185	0.0095			74,000	
	2	0.3545	0.3640	0.3750	-	-	0.0185	0.0095				
	3	0.3545	0.3640	0.3750	35	15	0.0185	0.0095				
	4	0.3545	0.3640	0.3750	-	-	0.0185	0.0095				

\*98 has 1.125 x 3.50 spacing

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

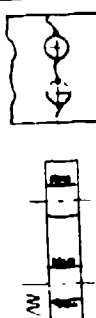

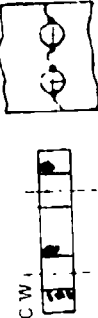
Ti-6Al-4V,  
2 1/2" D edge margin,  
open, C/W,  
70 ksi

TEST 4D5 (T) SPECIMEN 623080 DATE 10/22/13

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 7E	Interference (in.)	0.019	Nominal notch (in.)	0.375	Max. net stress (ksi)	70
Material	Ti-6Al-4V (annealed)	Sleeve type	Split	Process	Ream, C/W, ream	Max. test load (kip)	41.5
Width (in.)	3.375	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	1.50 x 3.50	Sleeve orientation	0°			Test frequency	4000 cpm
Edge margin (in.)	0.9375	Mandrel material	AISI 9260 steel			Test laboratory	Materials
Material grade (in.)	0.250	Mandrel taper (in/in)	0.045			Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max. diameter (in.)	0.353			Test machine	100 kip Vibraphore
		Lubrication	Fel Pro 300				

## FASTENER INSTALLATION

Type	
Fit	
Torque (in. ft)	

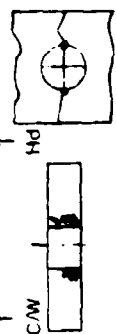
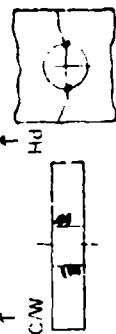

Specimen	Hole no.	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
101	1	0.3545	0.3745	0.3745	30	15	35	0.0185	0.0106			59,000	
	2	0.3550	0.3640	0.3745				0.0180	0.0090				
	3	0.3550	0.3540	0.3745	30	15	40	0.0180	0.0090				
	4	0.3550	0.3645	0.3745				0.0180	0.0090				
102	1	0.3545	0.3640	0.3745	25	10	30	0.0185	0.0085			104,000	
	2	0.3545	0.3640	0.3740				0.0185	0.0095				
	3	0.3545	0.3640	0.3745	30	15	35	0.0185	0.0095				
	4	0.3545	0.3640	0.3745				0.0185	0.0095				
103	1	0.3545	0.3640	0.3745	30	15	40	0.0185	0.0095			66,000	
	2	0.3545	0.3640	0.3745				0.0185	0.0095				
	3	0.3545	0.3640	0.3745	35	15	35	0.0185	0.0095				
	4	0.3545	0.3640	0.3745				0.0185	0.0095				

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
15 hole, single,  
C/W, net fit Hi-Lok,  
70 ksi

TEST 4E1 SPECIMEN 623080 DATE 11/18/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 9	Interference (in.)	0.14/0.15	Nominal hole size (in.)	0.250	Max net stress (ksi)	70
Material	Ti-6Al-4V	Sleeve type	Split	Process	Ream, C/W, ream	Max test load (kip)	12
Width (in.)	1.00	Sleeve thickness (in.)	0.008			Load ratio (R)	0.1
Hole spacing (in.)	1.00	Sleeve orientation	0°			Test frequency	600 cpm
E-jog margin (in.)	0.50	Mandrel material	H-11 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)	0.015	Type	Hi-Lok, prot hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.230	F.r (in.)	Net to 0.0005 clearance	Test machine	60- to 80- kip Riehle Los
		Lubrication	Fel Pro 300	Torque (in. lb)	80		

Specimen dash no.	H <sub>2</sub> O no.	Hole diameter (in.)			Hole finish (RHRI)				Coldwork expansion (in.)		Fastener size (in.)			Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit				
1	1	0.2315	0.2375	0.2485	25	15	20	0.0145	0.0060	0.2485	Net		124,950		
	2	0.2315	0.2375	0.2485	-	-	-	0.0145	0.0060	0.2485	Net				
	3	0.2315	0.2375	0.2485	25	10	25	0.0145	0.0060	0.2485	Net				
	4	0.2315	0.2375	0.2485	-	-	-	0.0145	0.0060	0.2485	Net				
2	1	0.2315	0.2375	0.2490	20	10	20	0.0145	0.0060	0.2485	0.0005		122,210		
	2	0.2315	0.2375	0.2490	-	-	-	0.0145	0.0060	0.2485	0.0005				
	3	0.2315	0.2375	0.2490	25	10	25	0.0145	0.0060	0.2485	0.0005				
	4	0.2315	0.2375	0.2490	-	-	-	0.0145	0.0060	0.2485	0.0005				
3	1	0.2315	0.2375	0.2490	-	-	-	0.0145	0.0060	0.2485	0.0005		60,780		
	2	0.2315	0.2375	0.2490	20	10	-	0.0145	0.0060	0.2485	0.0005				
	3	0.2315	0.2375	0.2490	-	-	20	0.0145	0.0060	0.2485	0.0005				
	4	0.2315	0.2375	0.2490	25	15	-	0.0145	0.0060	0.2485	0.0005				

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
15 hole, dual,  
C/W, prot hd Hi-Lok,  
70 ksi

TEST 4F1 SPECIMEN 620380 DATE 11/21/73

FATIGUE CONDITIONS

Max net stress (ksi) 70

Max test load (kip) 51.8

Load ratio (R) 0.1

Test frequency 600 cpm

Test laboratory Materials

Test engineer D. Reese

Test machine 60- to 80-kip  
Richie-Los

SPECIMEN DESCRIPTION

Fig. 8

Configuration Ti-6Al-4V (annealed)

Material Skin, 2.50, stringer, 1.0

Width (in.) 1.00

Hole spacing 1.00

Edge margin (in.) Skin, 1.25, stringer, 0.50

Material gauge (in.) 0.250

Surface treatment Shot peen

COLDWORK PROCESS

Interference (in.) 0.014/0.015

Sieve type Split

Sieve thickness (in.) 0.008

Sieve orientation 0°

Hole finish (RHR)

Mandrel material H-II steel

Mandrel taper (in/in) 0.015

Mandrel max diameter (in) 0.2305

Lubrication Fel Pro 300

FASTENER INSTALLATION

Type Hi-Lok, prot hd

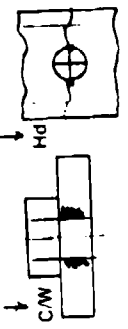
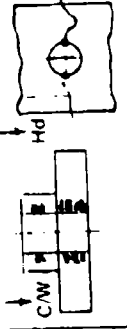
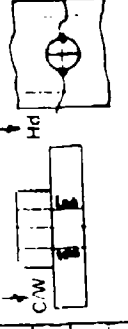
F<sub>1</sub> (in.) Net to 0.0005 clearance

Torque (in lb) 80

HOLE PREPARATION

Nominal hole size (in) 0.250

Process Ream, C/W, ream

Specimen dash no.	Hole no.	Hole diameter (in.)				Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream		Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	F-1		
4	1	0.2325	0.2395	0.2495	25	25	15	20	0.014	0.0070	0.2495	Net	40,190	
	2	0.2325	0.2395	0.2495	-	-	-	-	0.014	0.0070	0.2495	Net		
	3	0.1325	0.2395	0.2495	25	25	15	20	0.014	0.0070	0.2495	Net		
	4	0.2325	0.2395	0.2495	-	-	-	-	0.014	0.0070	0.2495	Net		
	1	0.2325	0.2395	0.2495	25	25	15	20	0.014	0.0070	0.2495	Net	39,840	
	2	0.2325	0.2395	0.2495	-	-	-	-	0.014	0.0070	0.2495	Net		
	3	0.2325	0.2395	0.2495	25	25	15	20	0.014	0.0070	0.2495	Net		
	4	0.2325	0.2395	0.2495	-	-	-	-	0.014	0.0070	0.2495	Net		
	1	0.2325	0.2395	0.2495	25	25	15	20	0.014	0.0070	0.2495	Net	47,330	
	2	0.2325	0.2395	0.2495	-	-	-	-	0.014	0.0070	0.2495	Net		
	3	0.2325	0.2395	0.2495	25	25	15	20	0.014	0.0070	0.2495	Net		
	4	0.2325	0.2395	0.2495	-	-	-	-	0.014	0.0070	0.2495	Net		

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
15-hole, dual,  
prot hd, Hi-Lok  
C/W, no postream,  
70 ksi

TEST: 4F2 SPECIMEN: 623080 DATE: 11/21/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 8	Interference (in.)	0.014-0.015	Nominal hole size (in.)	0.250	Max net stress (ksi)	70
Material	Ti-6Al-4V (annealed)	Sleeve type	Split	Process	Ream, C/W	Max test load (kip)	50.5
Width (in.)	Skin, 2.50, stringer, 1.00	Sleeve thickness (in.)	0.008			Load ratio (R)	0.1
Hole spacing	1.00	Sleeve orientation	0°			Test frequency	600 cpm
Edge margin (in.)	Skin, 1.25, stringer, 0.50	Mandrel material	H-11 steel			Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)	0.015	Type	Hi-Lok, prot hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.242	Fit (in.)	Net to 0.0005 clearance	Test machine	60- to 80-kip Riehle Los
		Lubrication	-50-90-300	Torque (in. lb)	80		

Specimen dash no	Hole no	Hole diameter (in.)				Hole finish (RH/R)				Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream		Before coldwork	After coldwork	After ream		Actual	Retained	Diameter	Fit		
7	1	0.2430	0.2500			20	10			0.0180	0.0070	0.2495	0.0005	98,040	Fajled at eighth fastener - stringer C/W Hd
	2	0.2430	0.2500			20	10			0.0180	0.0070	0.2495	0.0005		
	3	0.2430	0.2500			20	15			0.0180	0.0070	0.2495	0.0005		
	4	0.2430	0.2500			20	15			0.0180	0.0070	0.2495	0.0005		Failed at ninth fastener - skin C/W Hd
8	1	0.2430	0.2500			20	10			0.0180	0.0070	0.2495	0.0005	187,150	Failed at eighth fastener C/W Hd
	2	0.2430	0.2500							0.0180	0.0070	0.2495	0.0005		
	3	0.2430	0.2500			20	10			0.0180	0.0070	0.2495	0.0005		Failed at eighth fastener C/W Hd
	4	0.2430	0.2500							0.0180	0.0070	0.2495	0.0005		
9	1	0.2430	0.2500			20	10			0.0180	0.0070	0.2495	0.0005	191,330	Failed at ninth fastener C/W Hd
	2	0.2430	0.2500							0.0180	0.0070	0.2495	0.0005		
	3	0.2430	0.2500			20	10			0.0180	0.0070	0.2495	0.0005		
	4	0.2430	0.2500							0.0150	0.0070	0.2495	0.0005		Failed at ninth fastener

Skin, T1-6Al-4V  
Stringer, 2024-T851,  
15-hole, dual,  
C/W, prot hd, Hi Lok.

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST 4F3 SPECIMEN 623080 DATE 11/12/73

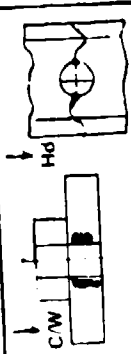
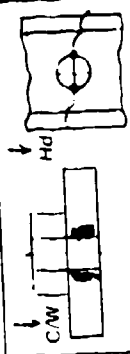
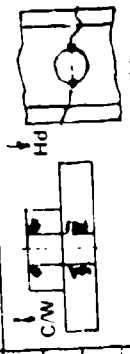
FATIGUE CONDITIONS  
64-T1-6Al-4V  
48-2024 T851  
Max net stress (ksi) 44.3  
Max test load (kip) 0.1  
Load ratio (R) 600 cpm  
Test frequency Materials  
Test laboratory D. Reese  
Test engineer 60 to 80 kip  
Test machine Richle-Los

HOLE PREPARATION  
Nominal hole size (in.) 0.250  
Process Ream, C/W, ream

COLDWORK PROCESS  
Interference (in.) 0.014-0.015  
Sleeve type Split  
Sleeve thickness (in.) 0.008  
Sleeve orientation 0°  
Mandrel material H II steel  
Mandrel taper (in./in.) 0.015  
Mandrel max diameter (in.) 0.2305  
Lubrication Fel Pro 300

FASTENER INSTALLATION  
Type Hi Lok, prot hd  
Fit (in.) Net to 0.0005 clearance  
Torque (in. lb) 80

SPECIMEN DESCRIPTION  
Fig. 8  
Configuration Skin, T1-6Al-4V (annealed)  
Material Stringer, 2024-T851  
Width (in.) Skin, 2.50 stringer, 1.0  
Hole spacing 1.00  
Edge margin (in.) Skin, 1.25, stringer 0.50  
Material gauge (in.) 0.250  
Surface treatment Shot peen

Specimen dash no.	Hole no.	Hole diameter (in.)		Hole finish (RRR)				Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
10	1	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net	61,590	
	2	0.2325	0.2400	0.2495				0.014	0.0075	0.2495	Net		
	3	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
	4	0.2325	0.2400	0.2495				0.014	0.0075	0.2495	Net	79,170	
11	1	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
	2	0.2325	0.1400	0.2495				0.014	0.0075	0.2495	Net		
	3	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
	4	0.2325	0.2400	0.2495				0.014	0.0075	0.2495	Net	64,620	
12	1	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
	2	0.2325	0.2400	0.2495				0.014	0.0075	0.2495	Net		
	3	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
	4	0.2325	0.2400	0.2495				0.014	0.0075	0.2495	Net		

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V  
high load transfer,  
C/W net fit Hi Lok,  
0.010 micarta,  
40 ksi

TEST 4G1 SPECIMEN 623080 DATE 10/9/73

## SPECIMEN DESCRIPTION

Fig. 10  
Configuration  
Material Ti-6Al-4V (annealed)  
Width (in.) 3  
Hole spacing (in.) 1.50  
Edge margin (in.) 0.75  
Material gage (in.) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS

Interference (in.) 0.019  
Slieve type Split  
Slieve thickness (in.) 0.010  
Slieve orientation 0°  
Mandrel material AISI 9260 steel  
Mandrel taper (in./in.) 0.045  
Mandrel max diameter (in.) 0.353  
Lubrication Fel Pro 300

## HOLE PREPARATION

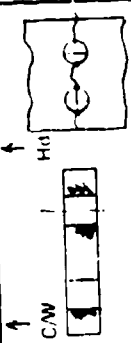
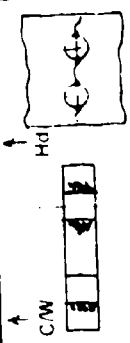
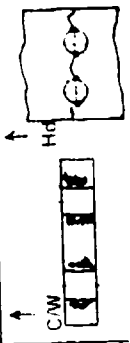

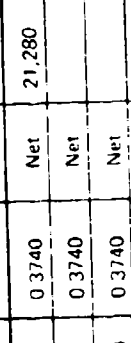
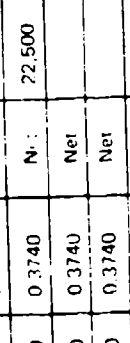
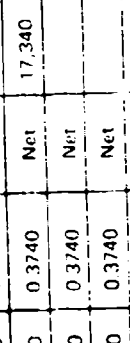

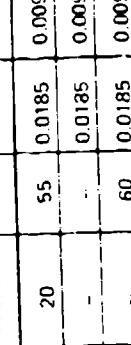
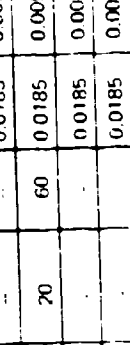
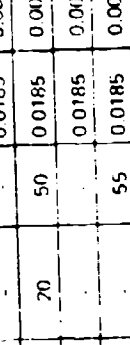

Nominal hole size (in.) 0.375  
Process Ream, C/W ream

## FASTENER INSTALLATION

Type Hi-Lok, prot hd  
Fit (in.) Net to 0.0005 clearance  
Torque (in. lb) 240

## FATIGUE CONDITIONS

Max net stress (ksi) 70  
Max test load (kip) 37  
Load ratio (R) 0.1  
Test frequency 600 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 60- to 80 kip  
Riehle-Los

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (IRHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks	
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Dia meter			Fit
1	1	0.3545	0.3635	0.3740	45	20	55	0.0185	0.0090	0.3740	Net	21,280	
	2	0.3545	0.3635	0.3740	-	-	-	0.0185	0.0090	0.3740	Net		
	3	0.3545	0.3635	0.3740	-	-	60	0.0185	0.0090	0.3740	Net		
	4	0.3545	0.3635	0.3740	-	-	-	0.0185	0.0090	0.3740	Net		
2	1	0.3545	0.3635	0.3740	45	20	60	0.0185	0.0090	0.3740	Net	22,500	
	2	0.3545	0.3635	0.3740	-	-	-	0.0185	0.0090	0.3740	Net		
	3	0.3545	0.3635	0.3740	60	-	-	0.0185	0.0090	0.3740	Net		
	4	0.3545	0.3635	0.3740	-	-	-	0.0185	0.0090	0.3740	Net		
3	1	0.3545	0.3635	0.3740	50	20	50	0.0185	0.0090	0.3740	Net	17,340	
	2	0.3545	0.3635	0.3740	-	-	-	0.0185	0.0090	0.3740	Net		
	3	0.3545	0.3635	0.3740	-	-	55	0.0185	0.0090	0.3740	Net		
	4	0.3545	0.3635	0.3740	-	-	-	0.0185	0.0090	0.3740	Net		

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti 6Al-4V,  
high load transfer,  
C/W, 0.002 clearance Hi-Lok,  
0.010 micarta,  
70 ksi

TEST 4G2 SPECIMEN 623080 DATE 10/9/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 10	Interference (in.)	0.019-0.020	Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti-6Al-4V (annealed)	Sleeve type	Split	Process	Ream, C/W, ream	Max test load (kip)	36.3
Width (in.)	3.00	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation	0°			Test frequency	600 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material gage (in.)	0.250	Mandrel taper (in./in.)	0.045	Type	Hi-Lok, prot hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.363	Fir (in.)	0.001-0.002 in. clearance	Test machine	60 to 80 kip Riehle-Los
		Lubrication	Fel-Pro 300	Torque (in. lb)	240		

Specimen dash no.	Hole diameter (in.)				Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
	Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	After ream	Actual	Retained	Diameter	Fir		
4	1	0.3545	0.3635	0.3760	65	25	60	0.0185	0.0090	0.3740	0.002	18,660	
	2	0.3545	0.3635	0.3760	-	-	-	0.0185	0.0090	0.3740	0.002		
	3	0.3545	0.3635	0.3760	70	-	-	0.0185	0.0090	0.3740	0.002		
	4	0.3545	0.3635	0.3760	-	-	65	0.0158	0.0090	0.3740	0.002		
5	1	0.3545	0.3630	0.3760	60	20	60	0.0185	0.0090	0.3740	0.002	20,640	
	2	0.3545	0.3630	0.3760	-	-	-	0.0185	0.0090	0.3740	0.002		
	3	0.3545	0.3630	0.3760	65	-	65	0.0185	0.0090	0.3740	0.002		
	4	0.3545	0.3630	0.3760	-	-	-	0.0185	0.0090	0.3740	0.002		
6	1	0.3545	0.3635	0.3760	55	20	70	0.0185	0.0090	0.3740	0.002	20,000	
	2	0.3545	0.3635	0.3760	-	-	-	0.0185	0.0090	0.3740	0.002		
	3	0.3545	0.3635	0.3760	-	-	-	0.0185	0.0090	0.3740	0.002		
	4	0.3545	0.3635	0.3760	-	-	-	0.0185	0.0090	0.3740	0.002		

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
high load transfer,  
C/W, 0.002 interference Hi-Lok,  
0.010 micarta,  
70 ksi

TEST 4G3 SPECIMEN 623080 DATE 10/10/73

## SPECIMEN DESCRIPTION

Fig. 10  
Ti-6Al-4V (annealed)  
3.00  
1.50  
0.75  
0.250  
Shot peen

## COLDWORK PROCESS

Interference (in.) 0.019-0.020  
Split  
0.010  
0°  
AISI 9260 steel  
0.045  
0.353  
Fel Pro 300

## HOLE PREPARATION

Nominal hole size (in.) 0.375  
Process Ream C/W, ream  
FASTENER INSTALLATION  
Type Hi-Lok, prot hd  
Fit (in.) 0.001-0.002 interference  
Torque (in lb) 240-250

## FATIGUE CONDITIONS

Max net stress (ksi) 70  
Max test load (kip) 37.5  
Load ratio (R) 0.1  
Test frequency 600 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 60- to 80 kip  
Riehle-Los

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHRI)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
7	1	0.3545	0.3635	0.3730	60	20	50	0.0185	0.0050	0.3740	0.001	24,140	
	2	0.3545	0.3635	0.3730	-	-	-	0.0185	0.0050	0.3740	0.001		
	3	0.3545	0.3635	0.3730	-	-	-	0.0185	0.0050	0.3740	0.001		
	4	0.3545	0.3635	0.3730	-	-	-	0.0185	0.0050	0.3740	0.001		
8	1	0.3545	0.3630	0.3730	60	20	50	0.0185	0.0085	0.3740	0.001	24,700	
	2	0.3545	0.3630	0.3730	-	-	-	0.0185	0.0085	0.3740	0.001		
	3	0.3545	0.3635	0.3730	-	-	-	0.0185	0.0050	0.3740	0.001		
	4	0.3545	0.3635	0.3730	-	-	-	0.0185	0.0050	0.3740	0.001		
9	1	0.3550	0.3635	0.3730	70	20	50	0.0180	0.0085	0.3740	0.001	26,630	
	2	0.3550	0.3630	0.3730	-	-	-	0.0180	0.0085	0.3740	0.001		
	3	0.3550	0.3630	0.3730	-	-	-	0.0180	0.0085	0.3740	0.001		
	4	0.3545	0.3630	0.3730	-	-	-	0.0185	0.0090	0.3740	0.001		

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
high load transfer,  
C/W, flush hd Hi-Lok,  
0.010 micarta,  
70 ksi

TEST 404 SPECIMEN 623080 DATE 10/30/73

## SPECIMEN DESCRIPTION

Fig. 10  
Configuration Ti-6Al-4V (annealed)  
Material 3.00  
Width (in.) 1.50  
Hole spacing (in.) 0.75  
Edge margin (in.) 0.250  
Material gauge (in.) Shot peen  
Surface treatment

## COLDWORK PROCESS

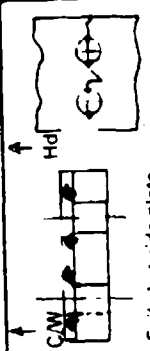
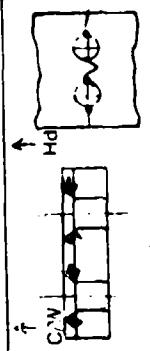
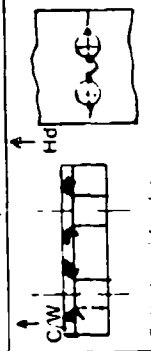
Interference (in.) 0.019-0.020  
Sleeve type Split  
Sleeve thickness (in.) 0.010  
Sleeve orientation 0°  
Mandrel material AISI 9260 steel  
Mandrel taper (in./in.) 0.045  
Mandrel max diameter (in.) 0.253  
Lubrication Fel Pro 300

## HOLE PREPARATION

Nominal hole size (in.) 0.375  
Process Ream, C/W, ream, csk  
FASTENER INSTALLATION  
Type Hi-Lok (flush hd)  
Fit (in.) Net to 0.0005 clearance  
Torque (in. lb) 240-250

## FATIGUE CONDITIONS

Max net stress (ksi) 70  
Max test load (kip) 37.3  
Load ratio (R) 0.1  
Test frequency 600 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 60- to 80 kip  
Riehle-Los

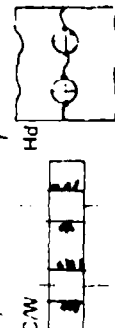
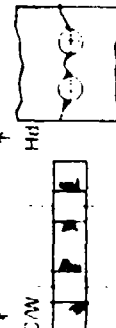
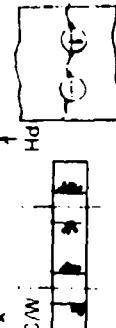
Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
-10	1	0.3550	0.3645	0.3740	25	15	0.0180	0.0095	0.3735	0.0005	11,580	
	2	0.3550	0.3645	0.3740	-	-	0.0180	0.0095	0.3735	0.0005		
	3	0.3550	0.3645	0.3740	30	15	0.0180	0.0095	0.3735	0.0005		
	4	0.3550	0.3645	0.3740	-	-	0.0180	0.0095	0.3735	0.0005		
-11	1	0.3545	0.3645	0.3740	30	15	0.0185	0.0100	0.3730	0.0010	6,200	
	2	0.3545	0.3650	0.3740	-	-	0.0185	0.0105	0.3730	0.0010		
	3	0.3545	0.3650	0.3740	25	15	0.0185	0.0105	0.3730	0.0110		
	4	0.3545	0.3645	0.3740	-	-	0.0185	0.0100	0.3735	0.0005		
-12	1	0.3550	0.3645	0.3740	30	15	0.0180	0.0095	0.3735	0.0005	11,170	
	2	0.3550	0.3650	0.3740	-	-	0.0180	0.0100	0.3735	0.0005		
	3	0.3550	0.3650	0.3740	25	15	0.0180	0.0100	0.3735	0.0005		
	4	0.3550	0.3645	0.3740	-	-	0.0180	0.0095	0.3735	0.0005		

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
high load transfer,  
C/W, net fit Hi-Lok,  
No micarta

TEST 4G5 SPECIMEN 623080 DATE 10/30/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 10	Interference (in.)	0.019	Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti-6Al-4V (annealed)	Sleeve type	Split	Process	0.010	Max test load (kip)	37.3
Width (in.)	3.00	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation	0°			Test frequency	600 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)	0.045	Type	Hi Lok, prot hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.353	Fit (in.)	Net to 0.0005 clearance	Test machine	60- to 80-kip Riehle-Los
		Lubrication	Fel Pro 300	Torque (in. lb)	240-250		

Specimen dash no.	Hole diameter (in.)				Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
	Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
.13	1	0.3650	0.3740	20	15	25	0.0180	0.0100	0.3735	0.0005	30,700	
	2	0.3650	0.3740	-	-	-	0.0180	0.0100	0.3735	0.0005		
	3	0.3650	0.3740	25	15	25	0.0180	0.0100	0.3735	0.0005		
	4	0.3650	0.3740	-	-	-	0.0180	0.0100	0.3735	0.0005		
.14	1	0.3650	0.3740	25	15	25	0.0180	0.0110	0.3735	0.0005	39,950	
	2	0.3645	0.3740	-	-	-	0.0180	0.0095	0.3740	Net		
	3	0.3650	0.3740	30	10	25	0.0180	0.0095	0.3740	Net		
	4	0.3650	0.3740	-	-	-	0.0180	0.0095	0.3735	Net		
.15	1	0.3650	0.3740	30	15	25	0.0180	0.0100	0.3735	0.0005	33,630	
	2	0.3650	0.3740	-	-	-	0.0180	0.0100	0.3735	0.0005		
	3	0.3650	0.3740	25	10	25	0.0180	0.0100	0.3735	0.0005		
	4	0.3650	0.3740	-	-	-	0.0180	0.0100	0.3735	0.0005		

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
high load transfer,  
C/W, net fit Hi-Lok,  
upset removed,  
70 ksi

TEST 4G6 SPECIMEN 623080 DATE 11/1/73

## SPECIMEN DESCRIPTION

Fig 10  
Configuration Ti-6Al-4V (annealed)  
Material  
Width (in.) 3.00  
Hole spacing (in.) 1.50  
Edge margin (in.) 0.75  
Material gage (in.) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS

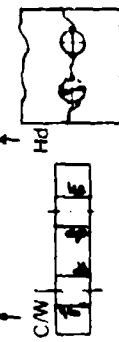
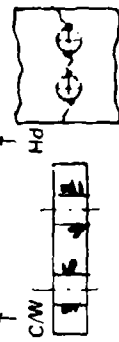
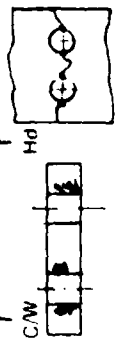
Interference (in.) 0.019  
Sleeve type Split  
Sleeve thickness (in.) 0.010  
Sleeve orientation 0°  
Mandrel material AISI 9260 steel  
Mandrel taper (in./in.) 0.045  
Mandrel max diameter (in.) 0.353  
Lubrication Fel Pro 300

## HOLE PREPARATION

Nominal hole size (in.) 0.375  
Process Ream, C/W, ream  
FASTENER INSTALLATION  
Type Hi Lok, prot hd  
Fit (in.) Net to 0.0005 clearance  
Torque (in. lb) 240 250

## FATIGUE CONDITIONS

Max net stress (ksi) 70  
Max test load (kip) 37.3  
Load ratio (R) 0.1  
Test frequency 600 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 60- to 80 kip  
Riehle-Los

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	After coldwork	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
.16	1	0.3550	0.3645	0.3740	25	15	20	0.0180	0.0950	0.3740	Net	98,140	
	2	0.3550	0.3645	0.3740	-	-	-	0.0180	0.0950	0.3740	Net		
	3	0.3550	0.3645	0.3740	25	15	20	0.0180	0.0950	0.3740	Net		
	4	0.3550	0.3645	0.3740	-	-	-	0.0180	0.0950	0.3740	Net		
.17	1	0.3550	0.3645	0.3740	25	15	20	0.0180	0.0950	0.3740	Net	36,180	
	2	0.3550	0.3645	0.3740	-	-	-	0.0180	0.0950	0.3740	Net		
	3	0.3550	0.3645	0.3740	20	15	20	0.0180	0.0950	0.3740	Net		
	4	0.3550	0.3645	0.3740	-	-	-	0.0180	0.0950	0.3740	Net		
.18	1	0.3550	0.3650	0.3740	30	15	20	0.0180	0.0950	0.3740	Net	31,890	
	2	0.3550	0.3650	0.3740	-	-	-	0.0180	0.0950	0.3740	Net		
	3	0.3550	0.3650	0.3740	25	15	20	0.0180	0.0950	0.3740	Net		
	4	0.3550	0.3650	0.3740	-	-	-	0.0180	0.0950	0.3740	Net		

Ti-6Al-4V,  
Taper, Lok,  
0.010-in. micarta,  
70 ksi

TEST 4G7 SPECIMEN 623080 DATE 11/1/73

## Fig. 10

Configuration	Fig. 10
Material	Ti-6Al-4V (annealed)
Width (in.)	3.00
Hole spacing (in.)	1.50
Edge margin (in.)	0.75
Material gauge (in.)	0.250
Surface treatment	Shot peen

## COLLIDWORK PROCESS

interference  
Sleeve type  
Sleeve thickness  
Sleeve orientation  
Mandrel material  
Mandrel taper  
Mandrel maximum  
lubrication

## WHOLE PREPARATION

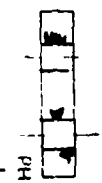
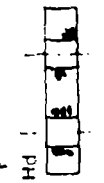

Nominal hole size (in)	0.375
Ream	

## FATIGUE CONDITIONS

Max net stress (ksi)	70
Max test load (kip)	37
Load ratio (R)	0.1
Test frequency	600 cpm
Test laboratory	Materials
Test engineer	D. Reese
Test machine	Materials
	Riehle Los

## FASTENER INSTALLATION

Type	Taper lok. prot. hd.
F <sub>1</sub> (in.)	Boeing class F (0.187-0.283)
Torque (in. lb)	240-250

Specimen dash no	Hole no	Fastener protrusion (in.)			Hole finish (RHRI)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
-19	1		0.2800				20				Class F	73,970	
	2		0.2800				-				Class F		
	3		0.2800				25				Class F		
	4		0.2800				-				Class F		
-20	1		0.2800				24				Class F	78,990	
	2		0.2800				-				Class F		
	3		0.2800				20				Class F		
	4		0.2800				20				Class F		
-21	1		0.2800				20				Class F	62,280	
	2		0.2800				-				Class F		
	3		0.2800				20				Class F		
	4		0.2800				-				Class F		

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
Taper Lok, push hd,  
0.010-in. micarta,  
70 ksi

TEST 4G8 SPECIMEN 623060 DATE 10/31/73

## SPECIMEN DESCRIPTION

Fig. 10  
Configuration  
Material Ti-6Al-4V (annealed)  
Width (in.) 3.00  
Hole spacing (in.) 1.50  
Edge margin (in.) 0.75  
Material grade (in.) 0.125 side plate  
Surface treatment Shot peen

## COLDWORK PROCESS

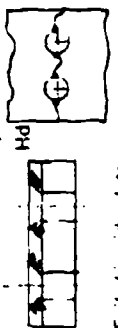
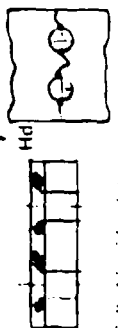
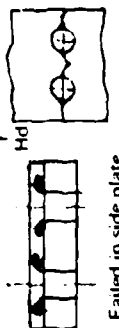
Interference  
Sleeve type  
Sleeve thickness (in.)  
Sleeve orientation  
Mandrel material  
Mandrel taper (in./in.)  
Mandrel max diameter (in.)  
Lubrication

## HOLE PREPARATION

Nominal hole size (in.) 0.375  
Process Ream  
FASTENER INSTALLATION  
Type Taper Lok flush hd  
Fit (in.) Boeing class F (0.187-0.289)  
Torque (in. lb) 240-250

## FATIGUE CONDITIONS

Max net stress (ksi) 70  
Max test load (kip) 37  
Load ratio (R) 0.1  
Test frequency 600 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 60- to 80 kip  
Riehle-Los

Specimen dash no	Hole no	Fastener protrusion (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
22	1		0.280				20				Class F	9,590	 Failed in side plate
	2		0.280				-				Class F		
	3		0.280				25				Class F		
	4		0.280				-						
23	1		0.280				20				Class F	8,450	 Failed in side plate
	2		0.280				-				Class F		
	3		0.280				30				Class F		
	4		0.280				-						
24	1		0.280				25				Class F	8,740	 Failed in side plate
	2		0.280				-				Class F		
	3		0.280				20				Class F		
	4		0.280				-						

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
ream only, net fit, Hi-Lok,  
0.010 in. micarta,  
70 ksi

TEST 4G9 SPECIMEN 623080 DATE 10/10/73

## SPECIMEN DESCRIPTION

Confirmation Fig. 10  
Material Ti-6Al-4V (annealed)  
Width (in.) 3.00  
Hole spacing (in.) 1.50  
Edge margin (in.) 0.75  
Material gage (in.) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS

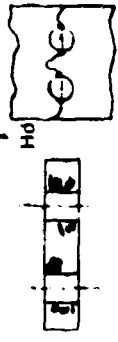
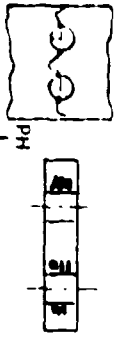
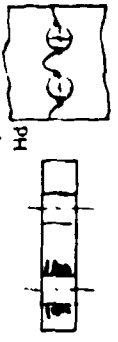
Interference \_\_\_\_\_  
Sleeve type \_\_\_\_\_  
Sleeve thickness (in.) \_\_\_\_\_  
Sleeve orientation \_\_\_\_\_  
Mandrel material \_\_\_\_\_  
Mandrel taper (in./in.) \_\_\_\_\_  
Mandrel max diameter (in.) \_\_\_\_\_  
Lubrication \_\_\_\_\_

## HOLE PREPARATION

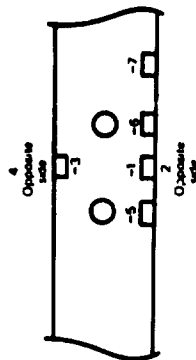
Nominal hole size (in.) 0.375  
Process Ream  
FASTENER INSTALLATION  
Type Hi-Lok, prot hd  
Fit (in.) Net to 0.001 clearance  
Torque (in. lb) 240

## FATIGUE CONDITIONS

Max net stress (ksi) 70  
Max test load (kip) 37  
Load ratio (R) 0.1  
Test frequency 600 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 60- to 80-kip  
Richie-Los

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHRI)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
25	1		0.3750				40			0.3740	0.001	19,050	
	2		0.3750				-			0.3740	0.001		
	3		0.3750				-			0.3740	0.001		
	4		0.3750				-			0.3740	0.001		
26	1		0.3750				-			0.3740	0.001	18,060	
	2		0.3750				50			0.3740	0.001		
	3		0.3750				-			0.3740	0.001		
	4		0.3750				-			0.3740	0.001		
27	1		0.3750				-			0.3740	0.001	10,940	
	2		0.3750				40			0.3740	0.001		
	3		0.3750				-			0.3740	0.001		
	4		0.3750				-			0.3740	0.001		

STRAIN GAGE READINGS AND CALCULATED STRESSES-TITANIUM



GAGE	Returned only / net area = 0.430										Coldworked / net area = 0.428										Returned after coldwork / net area = 0.410										With bolts installed																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
	0	5.0	13.5	21.0	28.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

σ - Stress reading for zero strain

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

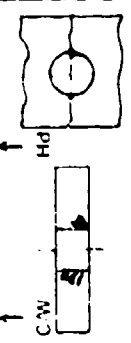
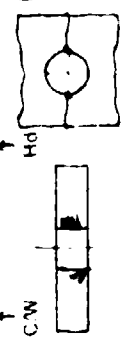
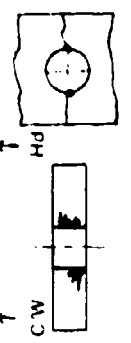
300 M,  
C/W, net fit, Hi Lok,  
sleeve process,  
110 ksi

TEST 4A1 SPECIMEN 623080 DATE 11/13/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference (in.)	0.018	Nominal hole size (in.)	0.375	Max net stress (ksi)	110
Material	300 M steel (220-300 ksi)	Sleeve type	Split	Process	Ream, C/W, ream	Max test load (kip)	31.3
Width (in.)	1.50	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation	0°			Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260	FASTENER INSTALLATION		Test laboratory	Materials
Material gage (in.)	0.250	Mandrel taper (in./in.)	0.045	Type	Hi-Lok, proof hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.3525	Fit (in.)	Net to 0.0005 clearance	Test machine	100-kip Vibrashore
		Lubrication	Fel Pro 300	Torque (in. lb)	240-250		

<sup>a</sup>Sleeve thinout was 0.002 in.

<sup>b</sup>Mandrel size reduced to 0.3513 after two holes; stabilized at 0.3510 after three holes

Specimen id# no.	Hole diameter (in.)				Hole finish (RHIT)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
	Before coldwork	After coldwork	After ream	After ream	Before coldwork	After ream	Actual	Retained	Diameter	Fit		
21	1	0.3550	0.3600	0.3740	20	15	0.0123	0.0050	0.3740	Net	93 000	
	2	0.3550	0.3600	0.3740	-	-	0.0123	0.0050	0.3740	Net		
	3											
	4											
22	1	0.3550	0.3595	0.3745	20	20	0.0120	0.0045	0.3740	0.0005	280 000	
	2	0.3550	0.3595	0.3745	-	-	0.0120	0.0045	0.3740	0.0005		
	3											
	4											
23	1	0.3550	0.3595	0.3745	20	15	0.0120	0.0045	0.3740	Net	178 000	
	2	0.3550	0.3595	0.3745	-	-	0.0120	0.0045	0.3740	Net		
	3											
	4											

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M,  
C/W net fit Hi-Lok,  
sleeve process,  
110 ksi

TEST 4A2 SPECIMEN 623080 DATE 11/13/73

## SPECIMEN DESCRIPTION

Fig. 2  
Configuration  
Material 300 M steel (270-300 ksi)  
Width (in.) 1.50  
Hole spacing (in.) 1.50  
Edge margin (in.) 0.75  
Material gauge (in.) 0.250  
Surface treatment: Shot peen

## COLDWORK PROCESS

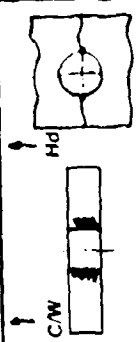
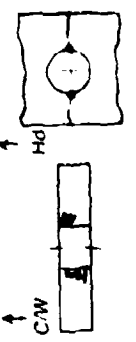
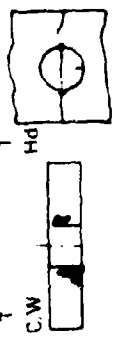
Interference (in.) 0.018  
Sleeve type Split  
Sleeve thickness (in.) 0.010  
Sleeve orientation 90°  
Mandrel material AISI 9260  
Mandrel taper (in./in.) 0.045  
Max. max diameter (in.) 0.3510  
Lubrication Fel Pro 300

## HOLE PREPARATION

Nominal hole size (in.) 0.375  
Process Ream, C/W, ream  
FASTENER INSTALLATION  
Type Hi-Lok, prot hd  
Fit (in.) Net to 0.0005 clearance  
Torque (in. lb) 240 250

## FATIGUE CONDITIONS

Max net stress (ksi) 110  
Max test load (kip) 31.3  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 100-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RA/R)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	F-t		
24	1	0.3550	0.3595	0.3740	20	10	15	0.0120	0.0045	0.3740	Net	103,000	
	2	0.3550	0.3595	0.3740	-	-	-	0.0120	0.0045	0.3740	Net		
	3												
	4												
25	1	0.3550	0.3600	0.3740	20	10	20	0.0120	0.0050	0.3740	Net	128,000	
	2	0.3550	0.3600	0.3740				0.0120	0.0050	0.3740	Net		
	3												
	4												
25	1	0.3545	0.3595	0.3740	25	15	15	0.0125	0.0050	0.3740	Net	114,000	
	2	0.3545	0.3595	0.3740				0.0125	0.0050	0.3740	Net		
	3												
	4												

300 M,  
C/W only, open,  
110 ksi

TEST 4A3 SPECIMEN 623080 DATE 9/7/73

## SPECIMEN DESCRIPTION

**Fig. 2**

Configuration

**Abstract**

1.50

Explain margin in ;

0.250

### Surface Treatment

Shot peen

## CONCLUSION

Interference (in)

2000

Slieve Donard

**Sleeve orien**

## Material

**Methodology**

Mandel max diam

### Lubrication

## HOLE PREPARATION

Normal body size (g)

**Process**

## Carbide (BAC 5972) FASTENER INSTALLATION

0.030  
T. 2.38

**Fir**  
**0.353**

**Fel Pro 300**

## FATIGUE CONDITIONS

110 Mean net stress (hPa)

May 1961 (p. 10)

Load ratio (R) 4000

Quantitative Test

D. R.  
Test Laboratory

**M**  
**Lead engineer**

Test maximum

[illegible]

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M,  
open, C/W,  
scored  
110 ksi

TEST 4A4 SPECIMEN 623080 DATE 5/7/73

## SPECIMEN DESCRIPTION

Fig. 2

Configuration 300 M (270-300 ksi)  
Material 300 M (270-300 ksi)  
Width (in.) 1.50  
Hole spacing (in.) 1.50  
Edge margin (in.) 0.75  
Material gage (in.) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS



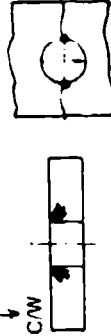
Interference (in.) 0.023  
Sleeve type Push, no sleeve  
Sleeve thickness (in.)  
Sleeve orientation  
Mandrel material Carbide (BAC 5972)  
Mandrel taper (in./in.) 0.030  
Mandrel max diameter (in.) 0.358  
Lubrication Fel Pro 300

## HOLE PREPARATION

Nominal hole size (in.) 3/8  
Process Ream, C/W, ream score  
Type  
Fit  
Torque (in.-lb)

## FATIGUE CONDITIONS

Max net stress (ksi) 110  
Max test load (kip) 31.2  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 100 kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHRI)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
.30	1	0.3350	0.3495	0.3735	25	15	20	0.023	0.0145			103,000	
	2	0.3350	0.3500	0.3735	-	-	20	0.023	0.0150				
	3												
	4												
.31	1	0.3350	0.3500	0.3740	25	10	25	0.023	0.0150			67,000	
	2	0.3350	0.3500	0.3745			25	0.023	0.0150				
	3												
	4												
.32	1	0.3350	0.3495	0.3735	25	15	20	0.023	0.0145			110,000	
	2	0.3350	0.3495	0.3735	-	-	20	0.023	0.0145				
	3												
	4												

300 M.  
drilled hole  
open, C/W  
170 ksi

TEST 4A5 SPECIMEN 623080 DATE 10/11/73

## Fig. 2

Configuration	300 M <sup>a</sup> Steel (270 300 ksi)	Fig. 2
Material		
Width (in.)	1.50	
Hole spacing	1.50	
Edge margin (in.)	0.75	
Material gauge (in.)	0.250	
Surface treatment	Shot peen	

## HOLE PREPARATION

Interference	0.023
Sleeve type	Push, no sleeve
Sleeve thickness (in.)	..
Sleeve orientation	..
Mandrel material	Carbide (BAC 5972)
Mandrel taper (in./in.)	0.030
Mandrel max diameter (in.)	0.357
Lubrication	Fel Pro 300

Nominal hole size (in.)	Process
3/8	Drill, C/W, ream

## FATIGUE CONDITIONS

Max net stress (ksi)	110
Max test load (kip)	31
Load ratio (R)	0.1
Test frequency	4000 cpm
Test laboratory	Materials
Test engineer	D. Reese
Test machine	100 kip Vibratory

## Type:

Type	Fit	Torque (in. lb)
1	1	1
2	2	2
3	3	3
4	4	4
5	5	5
6	6	6
7	7	7
8	8	8
9	9	9
10	10	10
11	11	11
12	12	12
13	13	13
14	14	14
15	15	15
16	16	16
17	17	17
18	18	18
19	19	19
20	20	20
21	21	21
22	22	22
23	23	23
24	24	24
25	25	25
26	26	26
27	27	27
28	28	28
29	29	29
30	30	30
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52	52	52
53	53	53
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55	55	55
56	56	56
57	57	57
58	58	58
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77	77	77
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91	91	91
92	92	92
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98	98	98
99	99	99
100	100	100

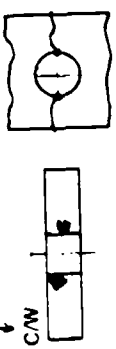
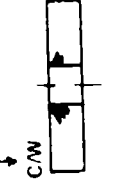
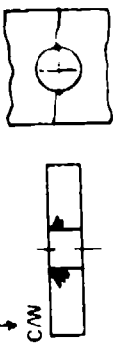
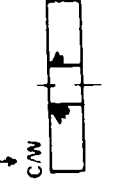
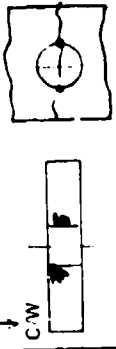
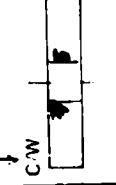
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# PHASE II-TASK 4- APPLICATION AND PROCESS PARAMETERS

300 M.  
abusive drill,  
open, C/W  
110 ksi

TEST 4A6 SPECIMEN 623080 DATE 10/11/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference	0.023	Nominal hole size (in.)	3/8	Max net stress (ksi)	110
Material	300 M steel (270-300 ksi)	Sleeve type	Push, no sleeve	Process	Drill, C/W, ream	Max test load (kip)	31.2
Width (in.)	1.50	Sleeve thickness (in.)	-			Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation	-			Test frequency	400 cpm
Edge margin (in.)	0.75	Mandrel material	Carbide (BAC 5972)			Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in/in)	0.030	Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.357	Fit		Test machine	100-kip vibraphore
		Lubrication	Fel Pro 300	Torque (in. lb)			

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
9	1	0.3350	0.03485	0.3730	60	10	20	0.022	0.0135			113,000	
	2	0.3350	0.03490	0.3730	-	-	-	0.022	0.0140				
	3												
	4												
10	1	0.3370	0.3490	0.3735	50	15	15	0.020	0.0120			150,000	
	2	0.3360	0.3490	0.3735	-	-	-	0.021	0.0125				
	3												
	4												
11	1	0.3400	0.3495	0.3730	60	10	20	0.017	0.0095			380,000	
	2	0.3350	0.3495	0.3735	-	-	-	0.022	0.00145				
	3												
	4												



# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M,  
1/32-postream,  
110 ksi

TEST 4AB SPECIMEN 623080 DATE 10/11/73

## SPECIMEN DESCRIPTION

Fig. 2  
Configuration 300 M steel (270-300 ksi)  
Material 1.50  
Width (in) 1.50  
Hole spacing 0.75  
Edge margin (in) 0.250  
Material gage (in) Shot peen  
Surface treatment

## COLDWORK PROCESS

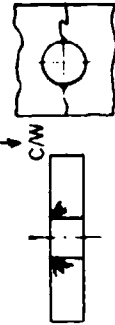
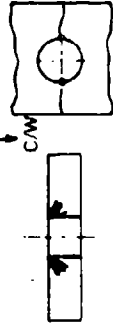
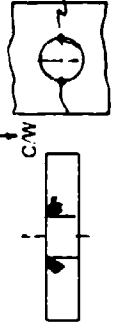
Interference 0.023  
Sleeve type Push no sleeve  
Sleeve thickness (in) -  
Sleeve orientation -  
Mandrel material Carbide (BAC 5972)  
Mandrel taper (in/in) 0.030  
Mandrel max diameter (in) 0.358  
Lubrication Fel Pro 300

## HOLE PREPARATION

Nominal hole size (in) 3/8  
Process Ream, C/W, ream (13/32)

## FATIGUE CONDITIONS

Max net stress (ksi) 110  
Max test load (kip) 30.3  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 100-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	F-11		
36	1	0.3345	0.3490	0.4055	30	15	20	0.0235	0.0145			248,000	
	2	0.3345	0.3490	0.4055	-	-	20	0.0235	0.0145				
	3												
	4												
37	1	0.3345	0.3490	0.4055	20	10	20	0.0235	0.0145			121,000	
	2	0.3345	0.3490	0.4055	-	-	20	0.0235	0.0145				
	3												
	4												
38	1	0.3345	0.3490	0.4055	25	12	20	0.0235	0.0145			209,000	
	2	0.3345	0.3490	0.4055	-	-	-	0.0235	0.0145				
	3												
	4												



# PHASE II-TASK 4- APPLICATION AND PROCESS PARAMETERS

300 M.  
0.060-in. gage mtl  
110 ksi

TEST 481 SPECIMEN 623080 DATE 9/24/73

## SPECIMEN DESCRIPTION

Configuration Fig. 2  
Material 300 M steel (270-300 ksi)  
Width (in) 1.50  
Hole spacing 1.50  
Edge margin (in) 0.76  
Material gage (in) 0.060  
Surface treatment Shot peen

## COLDWORK PROCESS

Interference 0.023  
Sleeve type Push, no sleeve  
Sleeve thickness (in) -  
Sleeve orientation -  
Mandrel material Carbide (BAC 5972)  
Mandrel taper (in/in) 0.030  
Mandrel max diameter (in) 0.358  
Lubrication Fel Pro 300

## HOLE PREPARATION

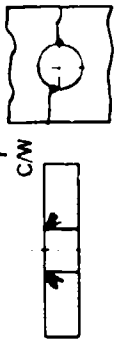
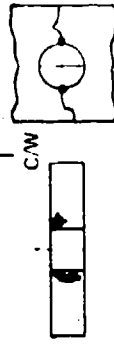
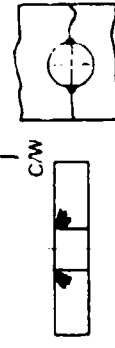
Nominal hole size (in) 3/8  
Process Ream, C/W, ream

## FATIGUE CONDITIONS

Max net stress (ksi) 110  
Max test load (kip) 3.6  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 36 kip Vibraphore

## FASTENER INSTALLATION

Type -  
Fit -  
Torque (in lb) -

Specimen dash no	Hole no	Hole diameter (in)			Hole finish (RHR)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
1	1	0.3345	0.3405	0.3735	25	12	15	0.0235	0.0060			71,000	
	2	0.3345	0.3440	0.3735	-	-	-	0.0235	0.0095				
	3												
	4												
2	1	0.3345	0.3440	0.3740	25	15	20	0.0235	0.0095			12,000	
	2	0.3395	0.3430	0.3740		-	-	0.0235	0.0085				
	3												
	4												
3	1	0.3345	0.3460	0.3735	20	10	15	0.0235	0.0115			47,000	
	2	0.3345	0.3470	0.3735	-	-	-	0.0235	0.0125				
	3												
	4												

# PHASE 1-TASK 4-APPLICATION AND PROCESS PARAMETERS

TEST 4C1 SPECIMEN 623080 DATE 9/10/73

300 M.  
1 hole, not C/W,  
filled,  
110 ksi

## SPECIMEN DESCRIPTION

Fig. 2

Configuration 300 M steel (270-300 ksi)

Material 1.50

Hole spacing 1.50

Edge margin (in.) 0.75

Material gauge (in.) 0.250

Surface treatment Shot peen

## COLDWORK PROCESS

Interference 0.023

Sleeve type Push, no sleeve

Sleeve thickness (in.) -

Sleeve orientation -

Mandrel material Carbide (BAC 5972)

Mandrel taper (in./in.) 0.030

Mandrel max diameter (in.) 0.358

Lubrication Fel Pro 300

## HOLE PREPARATION

Nominal hole size (in.) 3/8

Process Hole 1, ream

Hole 2, ream, C/W 1 ream

## FASTENER INSTALLATION

Type Hi-Lok prot hd

Fit Net to 0.0005 clearance

Torque (in. lb) 240-250

## FATIGUE CONDITIONS

Max net stress (ksi) 110

Max test load (kip) 30.6


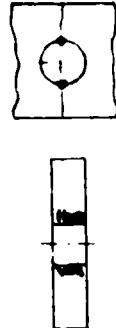

Load ratio (R) 0.1

Test frequency 400 cpm

Test laboratory Materials

Test engineer D. Reese

Test machine 100-kip vibraphore

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHRI)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
42	1	-	-	0.3740			30	-	-	0.3735	0.0008	43,000	 Failed in reamed hole
	2	0.3345	0.3490	0.3740	25	15	25	0.0235	0.0145	0.3735	0.0005		
	3												
	4												
43	1	-	-	0.3740			30	-	-	0.3735	0.0005	52,000	 Failed in reamed hole
	2	0.3350	0.3490	0.3740	25	12	20	0.0230	0.0140	0.3735	0.0005		
	3												
	4												
44	1	-	-	0.3740			30	-	-	0.3740	NET	33,000	 Failed in reamed hole
	2	0.3350	0.3490	0.3740	30	15	20	0.0230	0.0140	0.3740	NET		
	3												
	4												

# PHASE II-TASK 4- APPLICATION AND PROCESS PARAMETERS

300 M,  
0.002 clearance Hi-Lok,  
110 ksi

TEST 4C2 SPECIMEN 623080 DATE 9/24/73

## SPECIMEN DESCRIPTION

Configuration Fig. 2  
Material 300 M steel (270-300 ksi)  
Width (in) 1.50  
Hole spacing 1.50  
Edge margin (in) 0.75  
Material gage (in) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS

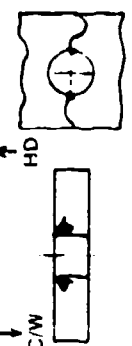
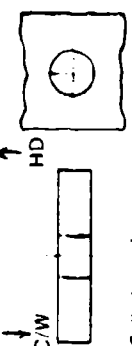
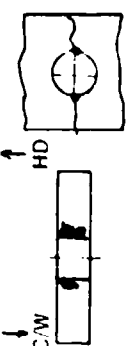
Interference 0.023  
Sleeve type Push no sleeve  
Sleeve thickness (in) -  
Sleeve orientation -  
Mandrel material Carbide (BAC 5972)  
Mandrel taper (in/in) 0.030  
Mandrel max diameter (in) 0.358  
Lubrication Fel-Pro 300

## HOLE PREPARATION

Nominal hole size (in) 0.375  
Process Ream, C/W ream  
FASTENER INSTALLATION  
Type Hi-Lok, prot hd  
Fit 0.002 clearance  
Torque (in lb) 240-250

## FATIGUE CONDITIONS

Max net stress (ksi) 110  
Max test load (kip) 31.3  
Load ratio (R) 0.1  
Test frequency 4000 gpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 100-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in)			Hole finish (RHR)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
-48	1	0.3335	0.3500	0.3755	25	10	25	0.0245	0.0165	0.3735	0.002	711,000	
	2	0.3335	0.3500	0.3755	-	-	-	0.0245	0.0165	0.3735	0.002		
	3												
	4												
-49	1	0.3335	0.3505	0.3755	30	15	25	0.0245	0.0170	0.3735	0.002	254,000	
	2	0.3335	0.3490	0.3755	-	-	-	0.0245	0.0155	0.3753	0.002		
	3												
	4												
-50	1	0.3335	0.3490	0.3755	28	10	25	0.0245	0.0155	0.3735	0.002	283,000	
	2	0.3335	0.3490	0.3755	-	-	-	0.0245	0.0155	0.3735	0.002		
	3												
	4												



# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M  
100° csk after C/W,  
110 ksi

TEST 4C4 SPECIMEN 623080 DATE 9/28/73

## SPECIMEN DESCRIPTION

Configuration Fig. 2  
Material 300 M steel (270-300 ksi)  
Width (in) 1.50  
Hole spacing (in.) 1.50  
Edge margin (in) 0.75  
Material gauge (in.) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS

Interference (in.) 0.023  
Sleeve type Push, no sleeve  
Sleeve thickness (in) -  
Sleeve orientation -  
Mandrel material Carbide (BAC 5972)  
Mandrel taper (in/in) 0.030  
Mandrel max diameter (in.) 0.357  
Lubrication Fel Pro 300

## HOLE PREPARATION

Nominal hole size (in) 0.375  
Process Ream, C/W, ream csk  
FASTENER INSTALLATION  
Type Hi-Lok (100° hd)  
F.i. (in.) Net to 0.0005 interference  
Torque (in lb) 240-250

## FATIGUE CONDITIONS

Max net stress (ksi) 110  
Max test load (kip) 31  
Load ratio (R) 0.1  
Test frequency 4000 gpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 100-kip Vitrashore

Specimen dash no	Hole no	Hole diameter (in.)				Hole finish (RHR)				Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	F.i.				
51	1	0.3340	0.3480	0.3735	25	10	20	0.0230	0.0140	0.3740	0.0005	9,993,000	 C/W      Hd      No failure		
	2	0.3340	0.3480	0.3735	-	-	-	0.0230	0.0140	0.3740	0.0005				
	3														
	4														
52	1	0.3335	0.3480	0.3735	-	-	-	0.0235	0.0145	0.3740	0.0005	7,760,000	 C/W      Hd      No failure		
	2	0.3340	0.3500	0.3740	40	20	20	0.0230	0.0150	0.3740	Net				
	3														
	4														
53	1	0.3340	0.3490	0.3735	25	12	20	0.0230	0.0150	0.3740	0.0005	1,510,000	 C/W      Hd      No failure		
	2	0.3340	0.3490	0.3735	-	-	-	0.0230	0.0150	0.3740	0.0005				
	3														
	4														





# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M.  
pretreated,  
80,000 cycles,  
110 ksi

TEST 4C7 (S) SPECIMEN 623080 DATE 10/16/73

## SPECIMEN DESCRIPTION

Fig. 2  
Material 300 M steel (270-300 ksi)  
Width (in.) 1.50  
Hole spacing (in.) 1.50  
Edge margin (in.) 0.75  
Material gage (in.) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS

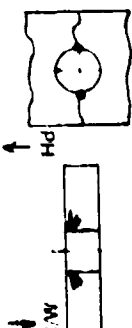
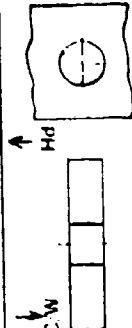
Interference (in.) 0.023  
Sleeve type Push, no sleeve  
Sleeve thickness (in.) -  
Sleeve orientation -  
Mandrel material Carbide (BAC 5972)  
Mandrel taper (in./in.) 0.030  
Mandrel max diameter (in.) 0.357  
Lubrication Fel Pro 300

## HOLE PREPARATION

Nominal hole size (in.) 3/8  
Process Ream undersize  
Fatigue (80,000 cycles) C.W., ream  
FASTENER INSTALLATION  
Type Hi-Lok prot hd  
F<sub>t</sub> (in.) Net to 0.0005 clearance  
Torque (in. lb) 240 250

## FATIGUE CONDITIONS

Max net stress (ksi) 110  
Max test load (kip) 32.6  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 100-kip Vibration

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)			Coldwork repairs on (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	After coldwork	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	F-t		
15	1	0.3330	0.3490	0.3735	20	10	20	0.024	0.0160	0.3735	Net	343,000	
	2	0.3330	0.3490	0.3735	-	10	-	0.024	0.0155	0.3735	Net		
	3												
	4												
17	1	0.3330	0.3490	0.3735	20	10	25	0.024	0.0160	0.3735	Net	7,508,000	
	2	0.3330	0.3490	0.3735	-	-	-	0.024	0.0160	0.3735	Net		
	3												
	4												No failure

<sup>a</sup>Specimen failed prior to reaching 80,000 cycles in initial fatigue cycling prior to C-W

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M,  
1 1/2-D edge margin,  
110 ksi

TEST 4D1(S) SPECIMEN 623080 DATE 10/23/73

## SPECIMEN DESCRIPTION

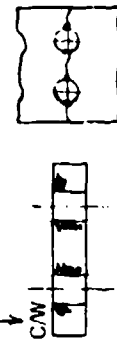


Fig. 7A

## COLDWORK PROCESS

## HOLE PREPARATION

## FATIGUE CONDITIONS

Configuration	300 M steel (270-300 ksi)	Interference (in.)	0.023	Nominal hole size (in.)	0.375	Max net stress (ksi)	110
Material	3.125	Sleeve type	Push, no sleeve	Process	Ream, C/W, ream	Max test load (kip)	65.4
Width (in.)	150 x 2.00	Sleeve thickness (in.)	-			Load ratio (R)	0.1
Hole spacing (in.)	0.562	Sleeve orientation	-			Test frequency	4000 cpm
Edge margin (in.)	0.250	Mandrel material	Carbide (BAC 5972)	FASTENER INSTALLATION		Test laboratory	Materials
Material gage (in.)	Shot peen	Mandrel taper (in./in.)	0.030	Type		Test engineer	D. Reese
Surface treatment		Mandrel max diameter (in.)	0.357	Fit		Test machine	100-kip Vibraphore
		Lubrication	Fel Pro 300	Torque (in. lb)			

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RH/R)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	After coldwork	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
60	1	0.3345	0.3485	0.3735	25	10	15	0.0225	0.0140			100,000	
	2	0.3345	0.3485	0.3735	-	-	-	0.0225	0.0140				
	3	0.3345	0.3485	0.3735	-	-	-	0.0225	0.0140				
	4	0.3345	0.3485	0.3735	-	-	-	0.0225	0.0140				
61	1	0.3345	0.3480	0.3735	25	10	10	0.0225	0.0135			170,000	
	2	0.3345	0.3480	0.3735	-	-	-	0.0225	0.0135				
	3	0.3345	0.3480	0.3735	-	-	-	0.0225	0.0135				
	4	0.3345	0.3480	0.3735	-	-	-	0.0225	0.0135				
63	1	0.3340	0.3490	0.3735	30	10	15	0.0230	0.0150			177,000	
	2	0.3340	0.3490	0.3735	-	-	-	0.0230	0.0150				
	3	0.3340	0.3490	0.3735	-	-	-	0.0230	0.0150				
	4	0.3340	0.3490	0.3735	-	-	-	0.0230	0.0150				

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M,  
2-D edge margin,  
110 ksi

TEST 402 (S) SPECIMEN 623080 DATE 10/22/73

## SPECIMEN DESCRIPTION

Fig. 7B

Configuration 300 M steel (270 300 ksi)  
Material 3.50  
Width (in.) 150 x 2.00  
Hole spacing (in.) 0.750  
Edge margin (in.) 0.250  
Material grade (in.) Shot peen  
Surface treatment

## COLDWORK PROC


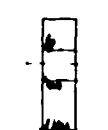

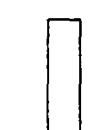
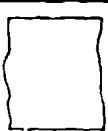
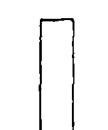
Interference (in.) 0.023 0.024  
Sleeve type Push, no sleeve  
Sleeve thickness (in.)  
Sleeve orientation  
Mandrel material Carbide (BAC 5972)  
Mandrel taper (in/in) 0.030  
Mandrel max diameter (in) 0.357  
Lubrication Fel Pro 300

## HOLE PREPARATION

Nominal hole size (in) 0.375  
Process Ream, C/W, ream  
FASTENER INSTALLATION  
Type  
Fit  
Torque (in lb)

## FATIGUE CONDITIONS

Max net stress (ksi) 110  
Max test load (kip) 75.7  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 100-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in)			Hole finish (RHR)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
65	1	0.3335	0.3485	0.3735	25	10	75	0.0235	0.0150			78,000	
	2	0.3335	0.3485	0.3735	-	-	-	0.0235	0.0155				
	3	0.3335	0.3485	0.3735	20	10	30	0.0235	0.0150				
	4	0.3335	0.3485	0.3735	-	-	-	0.0235	0.0150				
66	1	0.3335	0.3490	0.3735	30	15	20	0.0235	0.0155			44,000	
	2	0.3335	0.3490	0.3735	-	-	-	0.0235	0.0155				
	3	0.3335	0.3485	0.3735	25	10	15	0.0235	0.0150				
	4	0.3335	0.3485	0.3735	-	-	-	0.0235	0.0150				
67	1	0.3340	0.3485	0.3730	30	15	20	0.0230	0.0145			56,000	
	2	0.3340	0.3490	0.3730	-	-	-	0.0230	0.0145				
	3	0.3340	0.3485	0.3730	25	10	25	0.0230	0.0145				
	4	0.3340	0.3485	0.3730	-	-	-	0.0230	0.0145				

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M,  
2 1/2 D edge margin,  
110 ksi

TEST 4D3 (S) SPECIMEN 623080 DATE 10/23/73

## SPECIMEN DESCRIPTION

Configuration Fig. 7C  
Material 300 M steel (270-300 ksi)  
Width (in.) 3.875  
Hole spacing (in.) 150 x 2.00  
Edge margin (in.) 0.937  
Material gage (in.) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS

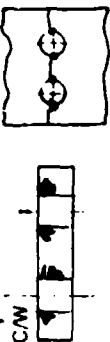
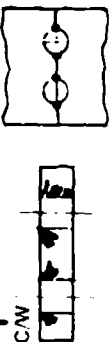
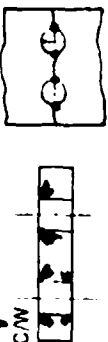
Interference (in.) 0.023, 0.024  
Sleeve type Push, no sleeve  
Sleeve thickness (in.) -  
Sleeve orientation -  
Mandrel material Carbide (BAC 5972)  
Mandrel taper (in./in.) 0.030  
Mandrel max diameter (in.) 0.357  
Lubrication Fel Pro 300

## HOLE PREPARATION

Nominal hole size (in.) 0.375  
Process Ream, C/W, ream  
FASTENER INSTALLATION  
Type -  
Fit -  
Torque (in. lb) -

## FATIGUE CONDITIONS

Max net stress (ksi) 110  
Max test load (kip) 86  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 100-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
-68	1	0.3340	0.3485	0.3735	25	10	20	0.023	0.0145			70,000	
	2	0.3340	0.3485	0.3735	-	-	-	0.023	0.0145				
	3	0.3340	0.3485	0.3735	-	-	-	0.023	0.0145				
	4	0.3340	0.3485	0.3735	-	-	-	0.023	0.0145				
-69	1	0.3340	0.3485	0.3735	30	10	15	0.023	0.0145			72,000	
	2	0.3340	0.3485	0.3735	-	-	-	0.023	0.0145				
	3	0.3340	0.3485	0.3735	-	-	-	0.023	0.0145				
	4	0.3340	0.3485	0.3735	-	-	-	0.023	0.0145				
-71	1	0.3340	0.3485	0.3740	30	10	20	0.023	0.0145			182,000	
	2	0.3340	0.3485	0.3740	-	-	-	0.023	0.0145				
	3	0.3340	0.3485	0.3740	-	-	-	0.023	0.0145				
	4	0.3340	0.3485	0.3740	-	-	-	0.023	0.0145				

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M,  
2½-D edge margin,  
110 ksi

TEST 4D4 (S) SPECIMEN 623080 DATE 10/23/73

## SPECIMEN DESCRIPTION

Fig. 7D

Configuration  
Material 300 M steel (270-300 ksi)  
Width (in.) 2.995  
Hole spacing (in.) 1.125 x 1.50  
Edge margin (in.) 0.9375  
Material gage (in.) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS

Interference (in.) 0.023-0.024  
Sleeve type Push, no sleeve  
Sleeve thickness (in.) -  
Sleeve orientation -  
Mandrel material Carbide (BAC 5972)  
Mandrel taper (in./in.) 0.030  
Mandrel max diameter (in.) 0.357  
Lubrication Fel Pro 300

## HOLE PREPARATION

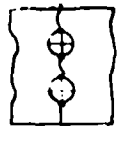
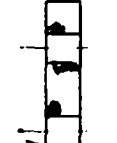
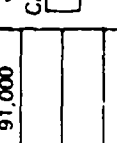

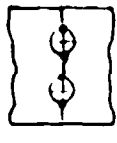
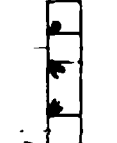
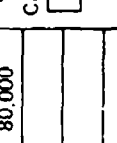

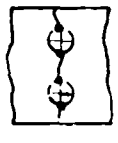
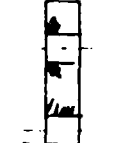
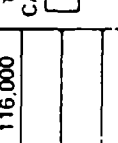

Nominal hole size (in.) 0.375  
Process Ream, C/W, ream

## FASTENER INSTALLATION

Type -  
Fit -  
Torque (in. lb) -

## FATIGUE CONDITIONS

Max net stress (ksi) 110  
Max test load (kip) 61.8  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 100-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
72	1	0.3335	0.3485	0.3740	25	10	20	0.0235	0.0150			91,000	
	2	0.3335	0.3485	0.3740	-	-	-	0.0235	0.0150				
	3	0.3335	0.3485	0.3740	-	-	-	0.0235	0.0150				
	4	0.3335	0.3485	0.3740	-	-	-	0.0235	0.0150				
73	1	0.3335	0.3485	0.3745	25	10	25	0.0235	0.0150			80,000	
	2	0.3335	0.3485	0.3740	-	-	-	0.0235	0.0150				
	3	0.3335	0.3485	0.3735	-	-	-	0.0235	0.0150				
	4	0.3335	0.3485	0.3735	-	-	-	0.0235	0.0150				
74	1	0.3340	0.3485	0.3735	25	10	20	0.0230	0.0145			116,000	
	2	0.3340	0.3485	0.3735	-	-	-	0.0230	0.0145				
	3	0.3340	0.3485	0.3735	-	-	-	0.0230	0.0145				
	4	0.3340	0.3485	0.3735	-	-	-	0.0230	0.0145				

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M.  
2 1/2 D edge margin,  
110 ksi

TEST 4D5 (S) SPECIMEN 623080 DATE 10/23/73

## SPECIMEN DESCRIPTION

Fig. 7E  
Configuration 300 M steel (270-300 ksi)  
Material 300 M steel (270-300 ksi)  
Width (in.) 3.375  
Hole spacing (in.) 150 x 1.50  
Edge margin (in.) 0.9375  
Material gage (in.) 0.250  
Surface treatment Shot peen

## COLDWORK PROCESS

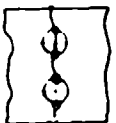
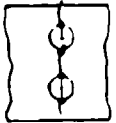
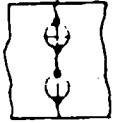

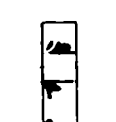
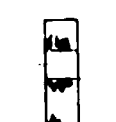


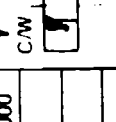
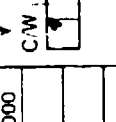
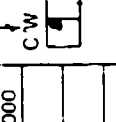

Interference (in.) 0.023 0.024  
Sleeve type Push, no sleeve  
Sleeve thickness (in.) -  
Sleeve orientation -  
Mandrel material Carbide (BAC 5972)  
Mandrel taper (in/in) 0.030  
Mandrel max diameter (in) 0.357  
Lubrication Fel Pro 300

## HOLE PREPARATION

Nominal hole size (in) 0.375  
Process Ream, C/W, ream  
Type -  
Fit -  
Torque (in lb) -

## FATIGUE CONDITIONS

Max net stress (ksi) 110  
Max test load (kip) 72.2  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 100-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in)				Hole finish (IRHR)				Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit				
76	1	0.3335	0.3485	0.3735	45	20	25	0.0235	0.0150					120,000	
	2	0.3335	0.3485	0.3735	-	-	-	0.0235	0.0150						
	3	0.3340	0.3485	0.3735	-	-	-	0.0230	0.0145						
	4	0.3340	0.3485	0.3735	-	-	-	0.0230	0.0145						
77	1	0.3340	0.3500	0.3730	50	25	20	0.0230	0.0160					145,000	
	2	0.3340	0.3485	0.3730	-	-	-	0.0230	0.0145						
	3	0.3340	0.3485	0.3730	-	-	-	0.0230	0.0145						
	4	0.3340	0.3490	0.3730	-	-	-	0.0230	0.0150						
78	1	0.3335	0.3485	0.3730	40	15	15	0.0235	0.0150					143,000	
	2	0.3335	0.3485	0.3735	-	-	-	0.0235	0.0150						
	3	0.3340	0.3485	0.3730	-	-	-	0.0230	0.0145						
	4	0.3340	0.3485	0.3730	-	-	-	0.0230	0.0145						

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M.  
high load transfer,  
CW, net fit Hi-Lok  
0.020 micarta,  
110 ksi

TEST 4E1 SPECIMEN 623080 DATE 11/17/73

## SPECIMEN DESCRIPTION

Fig. 10  
300 M (270-300 ksi)  
Material  
Width (in) 3.00  
Hole spacing 1.50  
Edge margin (in) 0.75  
Material gage (in) 0.250  
Surface treatment Shot 0.003  
Shim Thickness 0.020

## COLDWORK PROCESS

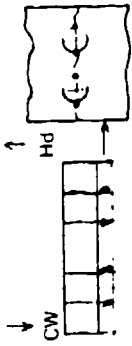
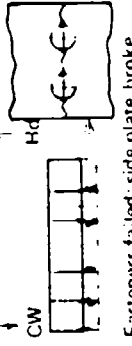
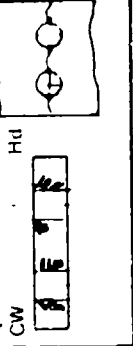
Interference (in) 0.023  
Sleeve type Push, no sleeve  
Sleeve thickness (in)  
Sleeve orientation  
Mandrel material Carbide (BAC 5792)  
Mandrel taper (in/in) 0.030  
Mandrel max diameter (in) 0.357  
Lubrication Fel Pro 300

## HOLE PREPARATION

Normal hole size (in) 0.375  
Process Ream, CW, ream  
Push, no sleeve  
Carbide (BAC 5792)  
Type Hi-Lok, prot hd  
Fit (in) Net to 0.005 interference  
Torque (in/lb) 240-250

## FATIGUE CONDITIONS

Max net stress (ksi) 110  
Max test load (kip) 62  
Load ratio (R) 0.1  
Test frequency 600 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 180 to 240-kip  
Riehle-Los

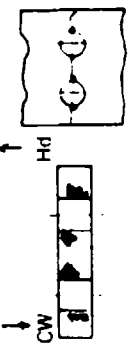
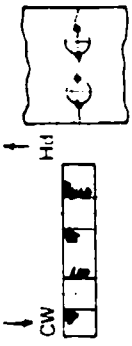
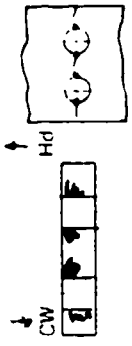
Specimen dash no	Hole no	Hole diameter (in)		Hole finish (RHR)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
1	1	0.3335	0.3485	0.3730	25	10	0.0235	0.0150	0.3735	0.0005	18,830	 <p>Fasteners failed; side plate broke</p>
	2	0.3335	0.3485	0.3730			0.0235	0.0150	0.3735	0.0005		
	3	0.3335	0.3485	0.3730	20	10	0.0235	0.0150	0.3730	Net		
	4	0.3335	0.3485	0.3730			0.0235	0.0150	0.3730	Net		
2	1	0.3335	0.3485	0.3730	20	10	0.0235	0.0150	0.3735	0.0005	17,240	 <p>Fasteners failed; side plate broke</p>
	2	0.3335	0.3485	0.3730			0.0235	0.0150	0.3735	0.0005		
	3	0.3335	0.3485	0.3735	25	10	0.0235	0.0150	0.3735	Net		
	4	0.3335	0.3485	0.3735			0.0235	0.0150	0.3735	Net		
3	1	0.3335	0.3485	0.3730	20	10	0.0235	0.0150	0.3735	0.0005	13,750	 <p>Fasteners failed; side plate broke</p>
	2	0.3335	0.3490	0.3730			0.0235	0.0155	0.3735	0.0005		
	3	0.3335	0.3490	0.3730	20	10	0.0235	0.0155	0.3730	Net		
	4	0.0335	0.3490	0.3730			0.0235	0.0155	0.3730	Net		

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M  
high load transfer,  
C/W, 0.0002 clearance Hi Lok,  
0.020 micarta,  
110 ksi

TEST 4E2 SPECIMEN 623080 DATE 11/17/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 10	Interference (in.)		0.023		Max net stress (ksi)	
	300 M (270 300 ksi)	Sleeve type		Push, no sleeve		Max test load (kip)	
Material		Sleeve thickness (in.)		-		Ream, C/W, ream	
Width (in.)	3.00	Sleeve orientation		-		Load ratio (R)	
Hole spacing (in.)	1.50	Mandrel material		Carbide (BAC 579)		Test frequency	
Edge margin (in.)	0.750	Mandrel taper (in/in)		0.030		Test laboratory	
Material gauge (in.)	0.250	Mandrel max diameter (in.)		0.3570		Test engineers	
Surface treatment:	Shot peen	Fillet		Fillet		Test machine	
Shim thickness (in.)	0.020	Lubrication		Fol Pro 300		180 to 240 - kip	
		Torque (in. lb)		240-250		Riehle-Los	

Specimen dash no.	Hole no.	Hole diameter (in.)			Hole finish (RMR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fillet		
4	1	0.3335	0.3485	0.3765	25	10	25	0.0235	0.0150	0.3735	0.3735	14 850	
	2	0.3335	0.3485	0.3765	-	-	-	0.0235	0.0150	0.3735	0.3735		
	3	0.3335	0.3485	0.3765	25	10	30	0.0235	0.0150	0.3735	0.0030		
	4	0.3335	0.3485	0.3765	-	-	-	0.0235	0.0150	0.3735	0.0030		
5	1	0.3335	0.3485	0.3760	25	10	-	0.0235	0.0150	0.3735	0.0025	21 820	
	2	0.3335	0.3485	0.3760	-	-	-	0.0235	0.0150	0.3735	0.0025		
	3	0.3335	0.3485	0.3755	25	10	-	0.0235	0.0150	0.3735	0.0020		
	4	0.3335	0.3485	0.3760	-	-	-	0.0235	0.0150	0.3735	0.0025		
6	1	0.3335	0.3485	0.3755	25	10	25	0.0235	0.0150	0.3730	0.0025	17 150	
	2	0.3335	0.3485	0.3755	-	-	-	0.0235	0.0150	0.3730	0.0025		
	3	0.3335	0.3485	0.3750	25	10	30	0.0235	0.0150	0.3730	0.0020		
	4	0.3335	0.3485	0.3750	-	-	-	0.0235	0.0150	0.3730	0.0020		

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST 4E3 SPECIMEN 623080 DATE 11/18/73

300 M  
high load transfer,  
C/W, 0.002 interference, Hi-Lok  
0.020 micarta  
110 ksi

## SPECIMEN DESCRIPTION

Fig. 10  
Configuration 300 M (270-300 ksi)  
Material 3.00  
Width (in.) 1.50  
Hole spacing (in.) 0.75  
Edge margin (in.) 0.250  
Material gage (in.) Shot peen  
Surface treatment Shim thickness (in.) 0.020

## COLDWORK PROCESS


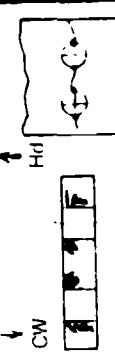
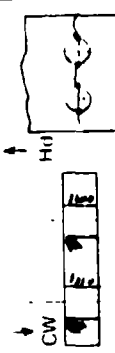
Interference (in.) 0.023  
Sleeve type Push, no sleeve  
Sleeve thickness (in.)  
Sleeve orientation  
Mandrel material Carbide (BAC 5792) FASTENER INSTALLATION  
Mandrel taper (in/in) 0.030  
Mandrel max diameter (in) 0.357  
Lubrication Fel Pro 300

## HOLE PREPARATION

Nominal hole size (in.) 0.0325  
Process Ream, C/W ream  
Type Hi-Lok, prot hd  
Fit (in.) 0.002 0.003 interference  
Torque (in/lb) 240-250

## FATIGUE CONDITIONS

Max test stress (ksi) 110  
Max test load (kip) 61  
Load ratio (R) 0.1  
Test frequency 600 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 180.240 kip  
Riehle Los

Specimen dash no	Hole no	Hole diameter (in)			Hole finish (RHRI)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Relieved	Diameter	Fit		
7	1	0.3335	0.3485	0.3715	25	10	20	0.0235	0.0150	0.3735	0.002	20,350	
	2	0.3335	0.3485	0.3715	-	-	-	0.0235	0.0150	0.3735	0.002		
	3	0.3335	0.3485	0.3715	25	10	20	0.0235	0.0150	0.3735	0.002		
	4	0.3335	0.3485	0.3715	-	-	-	0.0235	0.0150	0.3735	0.002		
8	1	0.3335	0.3485	0.3715	25	10	20	0.0235	0.0150	0.3735	0.002	15,040	
	2	0.3335	0.3485	0.3715	-	-	-	0.0235	0.0150	0.3735	0.002		
	3	0.3335	0.3485	0.3710	25	10	20	0.0235	0.0150	0.3735	0.0025		
	4	0.3335	0.3485	0.3710	-	-	-	0.0235	0.0150	0.3735	0.0025		
9	1	0.3335	0.3485	0.3710	25	10	20	0.0235	0.0150	0.3735	0.0025	21,930	
	2	0.3335	0.3485	0.3710	-	-	-	0.0235	0.0150	0.3735	0.0025		
	3	0.3335	0.3485	0.3710	25	10	20	0.0235	0.0150	0.3735	0.0025		
	4	0.3335	0.3485	0.3710	-	-	-	0.0235	0.0150	0.3735	0.0025		

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M  
high load transfer,  
C/W, flush hd, Hi-Lok  
0.020 micarta,  
110 ksi

TEST 4E4 SPECIMEN 623080 DATE 11/18/73

## SPECIMEN DESCRIPTION

Configuration Fig. 10  
Material 300 M (270-300 ksi)  
Width (in.) 3.00  
Hole spacing 1.50  
Edge margin (in.) 0.750  
Material gauge (in.) 0.125 side plates,  
0.250 center  
Surface treatment Shot peen  
Shim thickness (in.) 0.020

## COLDWORK PROCESS

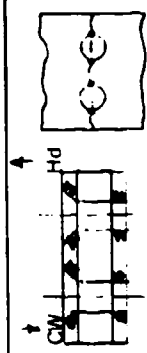
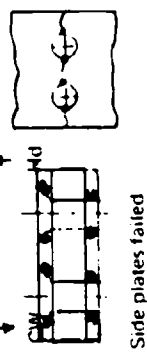
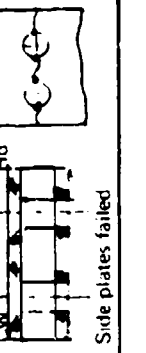
Interference (in.) 0.023  
Sleeve type push, no sleeve  
Sleeve thickness (in.) -  
Sleeve orientation -  
Mandrel material Carbide (BAC 5792)  
Mandrel taper (in./in.) 0.030  
Mandrel max diameter (in.) 0.357  
Lubrication Fel Pro 300

## HOLE PREPARATION

Nominal hole size (in.) 0.375  
Process Ream, C/W, ream, csk  
Type Hi-Lok, 1000 hd  
F-it (in.) Net to 0.0005 interference  
Torque (in. lb) 240-250

## FATIGUE CONDITIONS

Max net stress (ksi) 110  
Max test load (kip) 62  
Load ratio (R) 0.1  
Test frequency 600 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 180 to 240 kip  
Riehle-Los

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHRI)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	F-it		
-10	1	0.335	0.3485	0.3735	25	10	20	0.0235	0.0150	0.3735	Net	7,910	
	2	0.3335	0.3485	0.3735	-	-	-	0.0235	0.0150	0.3735	Net		
	3	0.0335	0.3485	0.3735	25	10	20	0.0235	0.0150	0.3735	Net		
	4	0.3335	0.3485	0.3735	-	-	-	0.0235	0.0150	0.3735	Net		
-11	1	0.3335	0.3485	0.3730	25	10	20	0.0235	0.0150	0.3735	0.0005	8,090	
	2	0.3335	0.3485	0.3730	-	-	-	0.0235	0.0150	0.3730	Net		
	3	0.3335	0.3485	0.3730	25	10	20	0.0235	0.0150	0.3735	0.0005		
	4	0.3335	0.3485	0.3730	-	-	-	0.0235	0.0150	0.3735	0.0005		
12	1	0.3335	0.3485	0.3735	30	15	-	0.0235	0.0150	0.3735	Net	9,300	
	2	0.3335	0.3485	0.3730	-	-	-	0.0235	0.0150	0.3735	0.0005		
	3	0.3335	0.3485	0.3730	30	15	-	0.0235	0.0150	0.3735	0.0005		
	4	0.3335	0.3485	0.3730	-	-	-	0.0235	0.0150	0.3735	0.0005		

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M  
high load transfer,  
reamed, net fit, Hi-Lok,  
0.020 micarta,  
110 ksi

TEST: 4E5 SPECIMEN 623080 DATE 11/12/73

## SPECIMEN DESCRIPTION

Fig. 10

Configuration 300 M (270 300 ksi)  
Material 3.00  
Width (in.) 1.50  
Hole spacing 0.75  
Edge margin (in.) 0.250  
Material grade (in.) Shot peen  
Surface treatment Shim Thickness (in.) 0.020

## COLDWORK PROCESS

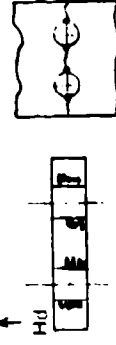
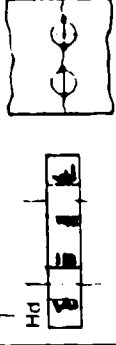
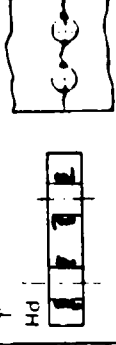
Interference  
Sleeve type  
Sleeve thickness (in.)  
Sleeve orientation  
Mandrel material  
Mandrel taper (in./in.)  
Mandrel max diameter (in.)  
Lubrication

## HOLE PREPARATION

Nominal hole size (in.) 0.375  
Process Ream  
FASTENER INSTALLATION  
Type Hi-Lok, prot hd  
Fit (in.) Net to 0.0005 clearance  
Torque (in. lb) 240-250

## FATIGUE CONDITIONS

Max net stress (ksi) 110 and 95  
Max test load (kip) 54 (95), 62 (110)  
Load ratio (R) 0.1  
Test frequency 600 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 180- to 240- kip  
Riehle-Los

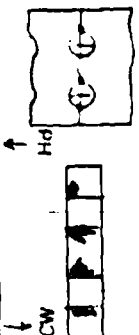
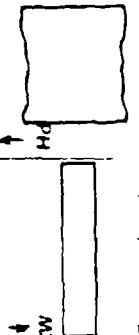
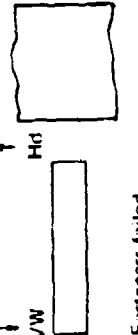
Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
13	1	0.3735				25			0.3735	Net	4,220	
	2	0.3735				-			0.3735	Net		
	3	0.3735				25			0.3735	Net		
	4	0.3735				-			0.3735	Net		
14	1	0.3735				25			0.3735	Net	8,040	
	2	0.3735				-			0.3735	Net		
	3	0.3735				25			0.3735	Net		
	4	0.3735				-			0.3735	Net		
15	1	0.3735				25			0.3735	Net	9,320	
	2	0.3735				-			0.3735	Net		
	3	0.3735				25			0.3735	Net		
	4	0.3735				-			0.3735	Net		

# PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

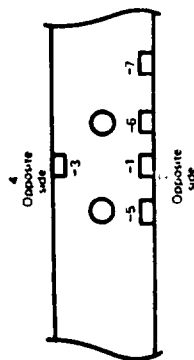
300 M  
C/W, net fit Ht-Lok,  
no micarta,  
110 ksi

TEST 4E6 SPECIMEN 623080 DATE 11/15/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 10	Interference (in.)	0.023	Nominal hole size (in.)	0.375	Max net stress (ksi)	122
Material	300 M (270 300 ksi)	Sleeve type	Push no sleeve	Process	Ream, C/W ream	Max test load (kip)	72.5
Width (in.)	3.00	Sleeve thickness (in.)	-			Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation	-			Test frequency	600 cpm
Edge margin (in.)	0.75	Material	Carbide (BAC 5792) FASTENER INSTALLATION			Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in/in)	0.030	Type	Hi Lok, prot hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.357	Fit (in.)	Net to 0.0005 clearance	Test machine	180 to 240 kip Richie Los
		Lubrication	Fel Pro 300	Torque (in lb)	240 250		

Specimen flash no	Hole no	Hole diameter (in.)				Hole finish (RHRL)				Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	After ream	Before coldwork	After coldwork	After ream	After ream	Actual	Retained	Diameter	Fit		
.16	1	0.3335	0.3485	0.3735	0.3735	20	10	20	20	0.0235	0.0150	0.3735	Net	7,150	
	2	0.3335	0.3485	0.3735	0.3735	-	-	-	-	0.0235	0.0150	0.3735	Net		
	3	0.3335	0.3485	0.3735	0.3735	25	10	20	20	0.0235	0.0150	0.3735	Net		
	4	0.3335	0.3485	0.3735	0.3735	-	-	-	-	0.0235	0.0150	0.3735	Net		
.17	1	0.3335	0.3485	0.3735	0.3735	20	10	20	20	0.0235	0.0150	0.3730	Net	9,660	
	2	0.3335	0.3485	0.3730	0.3730	-	-	-	-	0.0235	0.0150	0.3730	Net		
	3	0.3335	0.3485	0.3730	0.3730	20	10	20	20	0.0235	0.0150	0.3730	Net		
	4	0.3335	0.3485	0.3730	0.3730	-	-	-	-	0.0235	0.0150	0.3730	Net		
.18	1	0.3340	0.3485	0.3740	0.3740	30	10	20	20	0.0230	0.0145	0.3740	Net	11,770	
	2	0.3340	0.3485	0.3735	0.3735	-	-	-	-	0.0230	0.0145	0.3735	Net		
	3	0.3335	0.3485	0.3735	0.3735	35	10	20	20	0.0235	0.0150	0.3735	Net		
	4	0.3335	0.3485	0.3735	0.3735	-	-	-	-	0.0235	0.0150	0.3735	Net		

## STRAIN GAGE READINGS AND CALCULATED STRESSES-STEEL

[illegible]

100-100000

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## COST STUDY

### Elemental Flow Times

### Normal man-minutes

Positioning - Hand drill	0.03		
Hand reamer	0.02		
Winslow drill	0.08		
Quackenbush drill	0.16		
Taperlok reamer	0.06		
Torque tool	0.05		
	<u>AL</u>	<u>Ti</u>	<u>SH</u>
Drilling - Hand drill	0.32	-	-
Winslow drill, regular hole (6000)	0.18	-	-
Winslow drill, Boeing PT bolt hole (HS-2)	0.10		
Winslow drill, Taperlok hole	0.19		
Quackenbush drill	-	0.62	3.1
Reaming - Manual, straight hole	0.04	-	-
Manual, tapered hole	0.16	-	-
Quackenbush, straight hole	-	0.84	0.84
Quackenbush, tapered hole	-	0.334	1.05
Pin ream, tapered hole	0.15	0.20	0.20
Bolts/nuts - Insert	0.06	0.06	0.06
Drive Boeing PT bolt	0.086	-	-
Drive Taperlok	0.08	0.12	0.15
Inspect protrusion (Taperlok)	0.08	0.08	0.08
Place nut	0.43	0.43	0.43
Torque nut, regular	0.05	0.05	0.05
Torque nut, HiLok	0.07	0.07	0.07
Primer/sealant	0.025	-	-
Inspection - Inspect regular hole	0.02	0.02	0.10
Inspect PT hole	0.04	0.04	0.04
Inspect tapered hole	0.12	0.36	0.40
Inspect flushness	0.03	0.03	0.03
Inspect C/W hole	0.04	0.04	0.04
Coldworking - Place sleeve	0.065	0.065	-
Insert and pull	0.050	0.050	-
Remove sleeve	0.02	0.02	-
Lubricate and bake	-	-	0.10
Push or squeeze mandrel	-	-	0.16

Process Times and Costs (at \$10.50/hr)

Normal man-minutes

1) Taperlok--protruding head

	<u>Aluminum</u>	<u>Titanium</u>	<u>Steel</u>
Prorated setup and sample plates	0.236	0.69	0.82
Position drill	0.08	0.16	0.16
Drill straight hole	—	0.62	3.10
Drill/csk tapered hole	0.19	—	—
Position reamer	—	0.16	0.16
Ream taper	—	0.334	0.105
Inspect hole	0.12	0.36	0.40
10% pin ream	0.015	—	—
100% pin ream	—	0.20	0.20
Insert bolt	0.06	0.06	0.06
Inspect protrusion	0.08	0.08	0.08
Drive bolt	0.08	0.12	0.15
Install nut	0.43	0.43	0.43
Torque nut	0.05	0.05	0.05
Inspect flushness	0.03	0.03	0.03
14% PF&D*	<u>0.192</u>	<u>0.468</u>	<u>0.80</u>

Total normal man-minutes

1.563      4.210      6.545

Labor cost

\$0.274      \$0.735      \$1.14

Cutter cost/hole—drill

0.03      0.015      0.135

Cutter cost/hole—Taperlok reamer

—      0.11      0.84

Total installation cost

\$0.304      \$0.86      \$2.115

Steel Taperlok pin      \$0.54

Titanium Taperlok pin      0.97

Steel nut      0.07

Titanium seal nut      0.43

Total costs/installation

Steel Taperlok and steel nut

\$0.91      \$1.47      \$2.73

Steel Taperlok and seal nut

1.27      1.83      3.09

Titanium Taperlok and steel nut

1.34      1.90      3.16

Titanium Taperlok and seal nut

1.70      2.36      3.52

\*Personal fatigue and delay

2) Coldworked holes with titanium Hi-Loks—protruding head

	<u>Normal man-minutes</u>		
	<u>Aluminum</u>	<u>Titanium</u>	<u>Steel</u>
Prorated setup	0.110	0.110	0.25
Position drill	0.08	0.16	0.16
Drill straight hole	0.10	0.62	3.10
Inspect hole—sample	0.01	0.01	0.01
Place sleeve on mandrel	0.065	0.065	
Insert and pull	0.050	0.050	
Remove sleeves	0.020	0.020	—
Drylube hole	—	—	0.10
Place aligner on mandrel	—	—	0.02
Insert mandrel	—	—	0.03
Position part on yoke and push	—	—	0.16
Inspect hole	0.02	0.02	0.02
Position reamer	—	0.16	0.16
Postream	0.04	0.84	0.84
Insert bolt	0.06	0.06	0.06
Place nut	0.43	0.43	0.43
Torque nut	0.07	0.07	0.07
14% PF&D	<u>0.147</u>	<u>0.376</u>	<u>0.76</u>
Total normal man-minutes	1.202	2.991	6.17
Labor cost	\$0.21	\$0.523	\$1.08
Cutter cost/hole—drill	—	0.015	0.135
Cutter cost/hole—ream	—	0.021	0.21
C/W sleeve cost	0.14	0.14	—
Mandrel cost	—	—	0.30
Total installation cost	<u>\$0.35</u>	<u>\$0.699</u>	<u>\$1.725</u>
Titanium Hi-Lok pin	0.31		
Aluminum collar	0.05		
Aluminum seal nut	0.14		
<u>Total costs/installation</u>	<u>Aluminum</u>	<u>Titanium</u>	<u>Steel</u>
C/W holes with titanium Hi-Lok plus aluminum collar	\$0.71	\$1.06	\$2.09
C/W holes with titanium Hi-Lok plus aluminum seal nut	0.80	1.15	2.18

3) Coldworked holes with steel lockbolts and 10% steel Hi-Loks

	<u>Normal man-minutes</u>		
	<u>Aluminum</u>	<u>Titanium</u>	<u>Steel</u>
Prorated setup	0.110	0.110	0.25
Position drill	0.08	0.16	0.16
Drill straight hole	0.10	0.62	3.10
Inspect hole--sample	0.01	0.01	0.01
Place sleeve on mandrel	0.065	0.065	-
Insert and pull	0.050	0.05	-
Remove sleeves	0.02	0.02	-
Drylube hole	-	-	0.10
Place aligner on mandrel	-	-	0.02
Insert mandrel	-	-	0.03
Position part as yoke and push	-	-	0.16
Inspect hole	0.02	0.02	0.02
Position reamer	0.01	0.16	0.16
Postream	0.04	0.84	0.84
Insert lockbolt--90%	0.054	0.054	0.054
Place collar--90%	0.02	0.02	0.02
Pull lockbolt and swage collar--90%	0.07	0.07	0.07
Insert Hi-Lok--10%	0.006	0.006	0.006
Place nut--10%	0.043	0.043	0.043
Torque nut--10%	0.007	0.007	0.007
14% PF&D	0.099	0.315	0.705
Total normal man-minutes	0.804	2.570	5.755
Labor cost	\$0.14	\$0.45	\$1.01
Cutter cost--drill	-	0.015	0.135
Cutter cost--reamer	-	0.021	0.21
C/W sleeve cost	0.14	0.14	-
Mandrel cost	-	-	0.30
Total installation cost	\$0.28	\$0.626	\$1.655
Steel lockbolt pin	\$0.09		
Aluminum seal collar	0.03		
Steel Hi-Lok pin	0.17		
Aluminum seal nut	0.14		
Total installed costs	<u>Aluminum</u>	<u>Titanium</u>	<u>Steel</u>
C/W holes with 90% steel lockbolts, 10% steel Hi-Loks	\$0.42	\$0.77	\$1.80

4) Interference-fit straight-shank bolt

		<u>Normal man-minutes</u>		
		<u>Aluminum</u>	<u>Titanium</u>	<u>Steel</u>
Prorated setup and sample plates		0.19	0.36	—
Position drill		0.08	0.16	—
Drill straight hole		0.10	0.62	—
Position reamer		—	0.16	—
Ream		—	0.84	—
Inspect sample		0.04	0.04	—
Insert bolt		0.06	0.06	—
Drive bolt		0.08	0.12	—
Place nut		0.43	0.43	—
Torque nut		0.07	0.07	—
14% PF&D		<u>0.147</u>	<u>0.40</u>	<u>—</u>
Total normal man-minutes		1.197	3.26	—
Labor cost		\$0.21	\$0.57	
Cutter cost/hole—drill		—	0.015	
Cutter cost/hole—reamer		—	0.021	
Total installation cost		<u>\$0.21</u>	<u>\$0.606</u>	
Interference-fit titanium pin	0.34			
Aluminum collar	0.05			
Aluminum seal nut	0.14			
<u>Total costs/installation</u>		<u>Aluminum</u>	<u>Titanium</u>	<u>Steel</u>
Interference-fit titanium pin with aluminum collar		\$0.60	\$1.00	—
Above with aluminum seal nut		0.69	1.09	

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13. ABSTRACT In this 21-month program, optimized process parameters for sleeve coldworking of fastener holes have been developed, and the effects of process and application parameters on structural performance have been defined for selected aluminum, titanium, and high-strength steel alloys. The sleeve coldworking process for fastener holes is a process that uses a tapered mandrel in conjunction with a disposable, prelubricated sleeve to compressively prestress a significant size zone around each hole which offsets the stress concentration of the hole itself. The sleeve method allows higher degrees of prestressing than possible with other methods and offers potential for significant improvements in fatigue performance. In addition, it does not require precision controls germane to other fatigue-rated hole preparation/fastener installation systems. This technical report covers the results of this 21-month program. In addition to definition of optimized methods and the effects of process and application variations upon structural performance, the results include performance and economics comparisons for the process with other fatigue-rated hole preparation/fastener systems.		

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Hole coldworking						
Hole prestressing						
Prestressing						
Coining						
Mandrel/sleeve prestressing						
Mandrel/sleeve coining						
Mandrel/sleeve coldworking						

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